DOCUMENT RESUME

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IDENTIFIERS	Military Curriculum Project; *Surveying (Engineering)

ABSTRACT

These programmed instruction materials for a postsecondary-level course in map compilation and math review comprise one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. The seventeen lessons include Freehand Lettering; Review of Math (with additional individual lessons on ratio and proportion, algebra review, powers and roots, and trigonometry); Glossary of Mapping, Charting and Geodetic Terms; Map Marginal Information; Common Skills in Map Reading; Compilation from Map Sources "Pull-Ups"; Road Dimensions; The Engineer's Scale; Planetable Surveying; Construction Surveying; Logical Contouring; Resolution of Uncorrected Distance; Determination of Stadia Constant; Determination of "c"; Horizontal Circle Reading Wild T-2 Theodolite; Strength of Figure for Triangulation Reconnaissance; and Relative Orientation of Irregular Terrain Models. Lessons are broken down into "frames," which teach with words and or pictures. Students then complete a response or perform a described action. Lessons also provide the lesson objective and some self-tests, review exercises, and handouts. (YLB)

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Military Curricula for Vocational & Technical Education

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MAP COMPILATION AND MATH REVIEW

3-29

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

[illegible]

CE 024 524

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

This military technical training course has been selected and adapted by The Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University · 1960 Kenny Road · Columbus, Ohio 43210
Tel: (614) 486-3655 Cable: CTVOCEDOSU/Columbus, Ohio

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

MAP COMPILATION AND MATH REVIEW

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Relative Orientation of Irregular Terrain Models	978

Classroom Course

MAP COMPILATION AND MATH REVIEW

Developed by:

United States Army

Development and Review Dates:

February 1978

Occupational Area:

Target Audiences:

13 - Adult

Print Pages: 1063

Microfiche: 18

Availability:

Vocational Curriculum Coordination Centers

Contents:	Type of Materials:						Instructional Design:				Type of Instruction:	
	Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Group Instruction:	Individualized:
Freehand Lettering		●										●
Review of Math		●	●	●			●	●	●			●
Map Marginal Information		●			●		●	●	●			●
Common Skills in Map Reading		●			●				●			●
Road Dimensions		●					●					●
Engineer's Scale		●					●	●				●
Planetable Surveying		●						●				●
Logical Contouring		●						●				●
Resolution of Unconnected Distance		●					●	●				●
Determination of "C"		●										●
Horizontal Circle Reading Wild T-2 Theodolite		●					●	●				●
Strength of Figure for Triangulation Reconnaissance		●					●					●
Relative Orientation of Irregular Terrain Models		●					●					●

X Materials are recommended but not provided.

THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION

OSU
The Ohio State University

1960 Kenny Road
Columbus, Ohio 432
(614) 486-3655

Course Description:

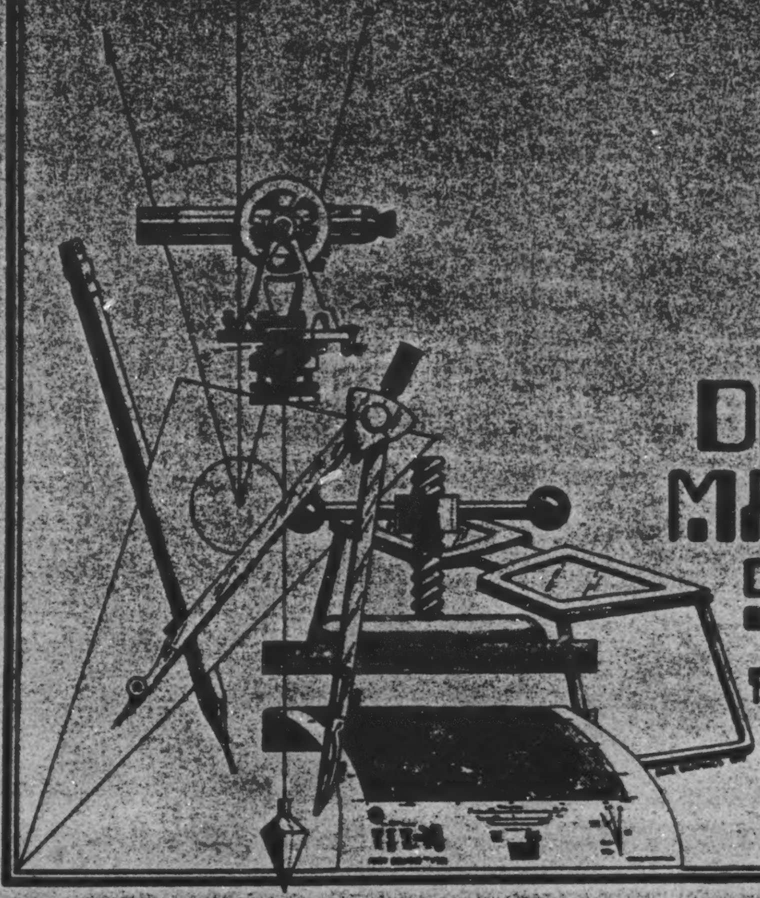
This package is a compilation of Programmed Instruction materials including the topics listed on the previous page under "Contents." The entire package is individualized in nature and contains all of the materials for student use.

1

PROGRAMMED LESSON

DMS NO. PI 223

FREEHAND LETTERING



DEFENSE
MAPPING
SCHOOL
FORT BELVOIR
VIRGINIA

FEB 1978

2

INSTRUCTIONS TO STUDENT

This programmed lesson is a WORKBOOK which combines "Self-Teaching" with Class-Teaching as you learn each step. The overall lesson information is broken into small steps called "frames". Each frame teaches with words, pictures, or both; then you are required to apply that bit of instruction by completing a response or doing a described action. The booklet is set up so that, when the book is open, the teaching or questioning part of the frame is on the left page; while the answer, picture, or action portion of that frame is on the facing right page.

To work and learn with this booklet, you read the left portion of the frame, then continue over to the right facing page and complete the answer (response) or do the described action. When that frame is completed, you turn the page for the next frame. If you have just completed a response frame, you will find in parenthesis ( ) a check on your last response. It is there for you to check your answer, NOT FOR COPYING. Instructors will be around to comment on your action frames and to offer personal assistance and advice. If you are doing the booklet in class, raise your hand when you need an instructor's advice before you try the next frame. Otherwise, just continue to the next frame.

This booklet is your property, it is not a test (other than testing yourself). Go through it at your own speed. Note that each page is divided by horizontal lines into A, B and C Levels. Continue thru the booklet on Level A before returning to the front to start Level B; then, work thru Level B and so on until you have completed the lesson.

The last set of frames directs you to do a practical exercise. Here you will make lettering guide lines and show how well you can do freehand lettering. This exercise will be turned in to the instructor, once it is completed.

OBJECTIVES OF THIS LESSON

Upon completion of this lesson you will know and recognize the style of freehand lettering recommended for military construction drawings. You will further be able to . . . . .

a. . . . recognize the value of lettering guide lines.

b. . . . form all letters and numerals with easy strokes, in a natural sequence, and in a stable style.

c. . . . compose those letters into clearly legible words, and space the words into easy-to-read sentences.

d. . . . properly form whole numbers and fractions.

e. . . . develop and practice habits that will make your freehand lettering a continually improving skill.

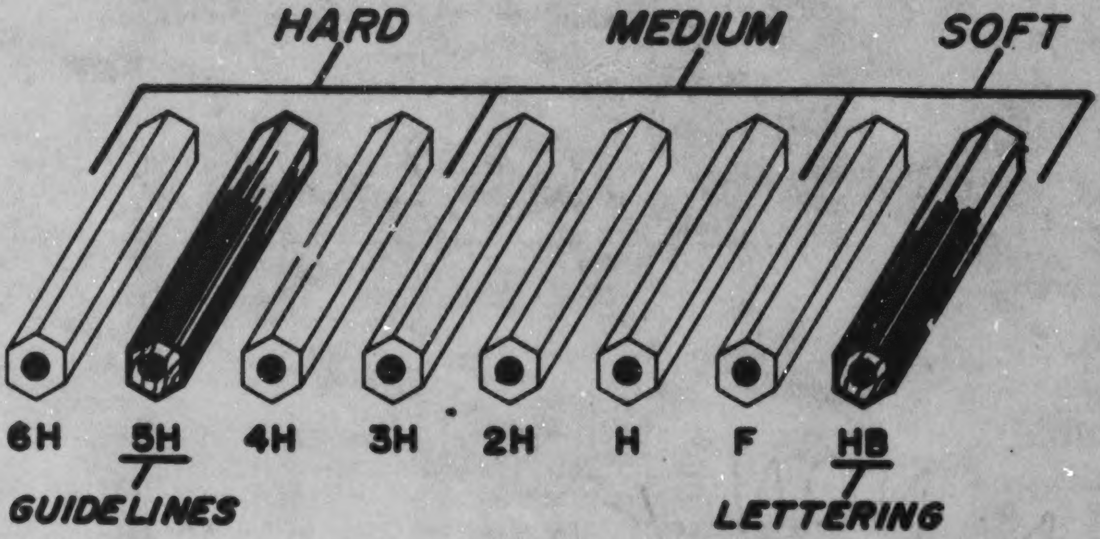
f. . . . demonstrate your ability to set up proper lettering guide lines, and do lettering at various sizes.

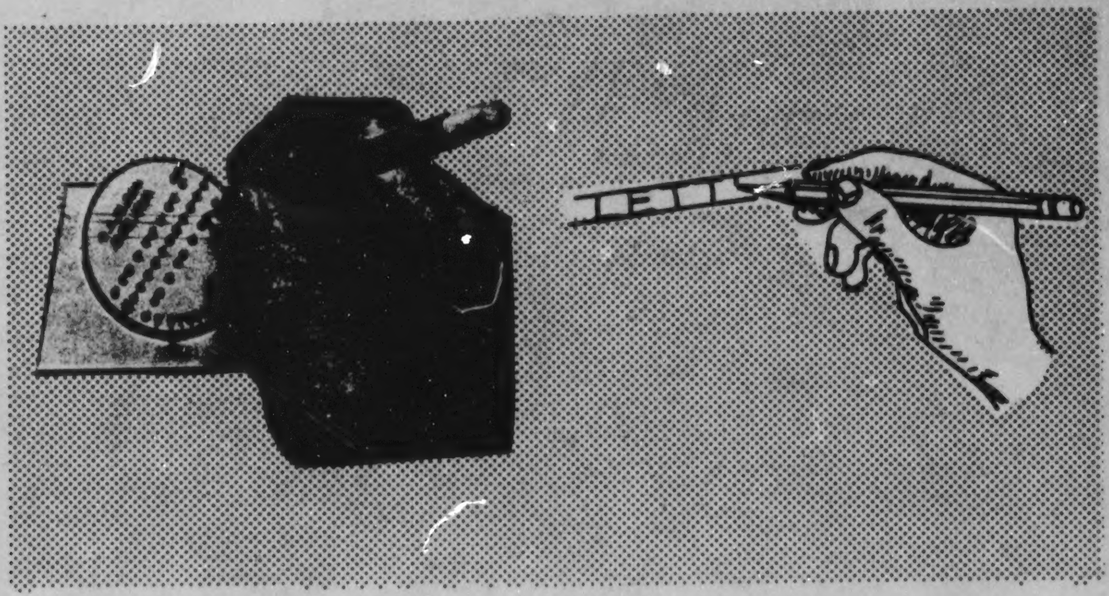
FINAL INSTRUCTIONS

Now, with "HB" pencil in hand and sandpaper pad handy, start Level A, frame #1 at the top of page 4. Work thru Level A (top of each succeeding page) before starting Level B, frame #19, etc.

You will be teaching yourself, but if you have a question, raise your hand and an instructor will assist you.

FREEHAND LETTERING


HARD
MEDIUM
SOFT
6H
5H
4H
3H
2H
H
F
HB
GUIDELINES
LETTERING



1.

The ability to letter well can be acquired by anyone who will PRACTICE faithfully and intelligently, as well as take the time to always follow the procedures outlined in this text.

LEVEL A

(Now complete the response on facing page)

DO NOT WORK BELOW THIS LINE UNTIL YOU HAVE
COMPLETED ALL FRAMES OF LEVEL A.

---

19. (Action)

LETTER STROKES

LEVEL B

Using the guidelines provided in Figure 7, practice clockwise and counter-clockwise curve strokes by repeating patterns as shown. Be sure to follow the direction of the arrows for all strokes as indicated in the illustration.

(proper spacing) 35.

LETTER SPACING

LEVEL C

Because of the variety in widths and shapes, letters must be spaced so that the void areas between them appear relatively equal.

Use the facing page to practice letter spacing by duplicating the illustrated words. Make an effort to match spacing of your letters with the provided samples shown in Figure 19.

6

1.

Response:

In order to acquire the ability to letter well, we must

____________________ faithfully and intelligently.

19.

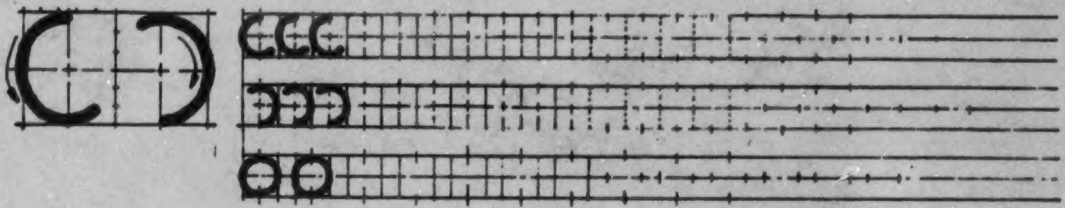


Figure 7

[redacted]G

35.

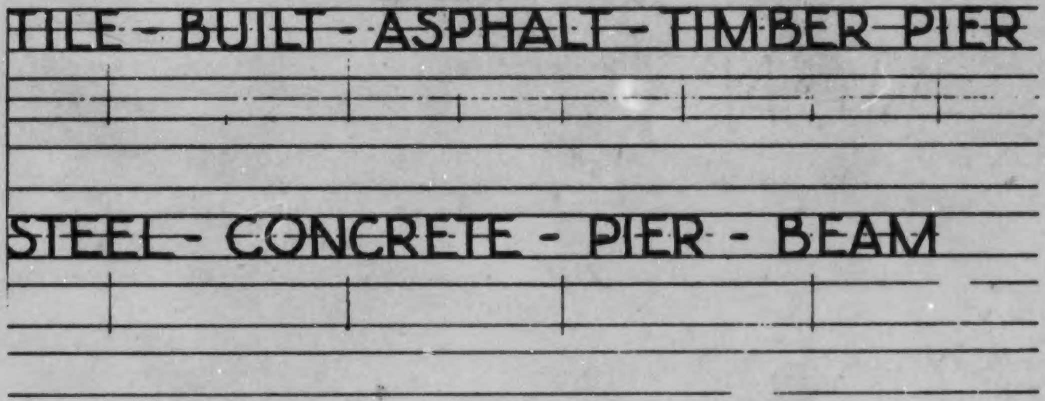

TILE - BUILT - ASPHALT - TIMBER PIER
STEEL - CONCRETE - PIER - BEAM

Figure 19

(practice) 2.

The only lettering style that will be taught in this drafting course is SINGLE-STROKE, VERTICAL, COMMERCIAL GOTHIC, CAPITAL LETTERING. This style is the lettering used on all types of drawings, and is the foundation for the beginner.

LEVEL A

(Complete response on facing page)

20.

RULE OF STABILITY

Letters, such as B, E, K, S, X, and Z, and the numbers 3 and 8, must be drawn smaller at the top than at the bottom to present an appearance of stability. This will counteract the optical illusion of letters or numbers appearing to " fall over ".

LEVEL B

36.

WORD SPACING

When spacing words, a logical separation is necessary --- not too far apart that the words lose their relationship to each other, and not too close that the words run together. A " rule-of-thumb " that can be followed in the spacing of words is: The space provided between words should be such that if the letter " I " were inserted between two words, they would appear as one word. (See Figure 20.)

LEVEL C

18

Response: 2.

The standard lettering style used on all drawings is

____________ - ____________, VERTICAL, COMMERCIAL GOTHIC, CAPITAL LETTERING.

Response: 20.

The top of the number 8 is drawn ____________ than the bottom to give the number a firm base to support itself.

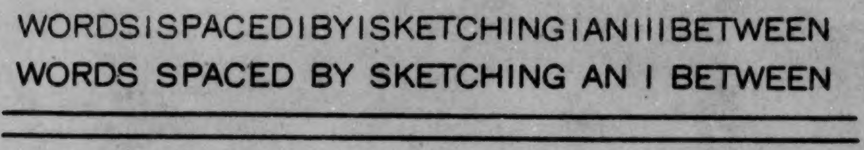

WORDSISPACEDIBYISKETCHINGIANIIIBETWEEN
WORDS SPACED BY SKETCHING AN I BETWEEN

Figure 20

Response: 36.

The letter __________ is used as a guide for spacing words.

Using the guidelines provided in Figure 20, letter the phrase shown above the guidelines.

(single-stroke)

3.

A SINGLE - STROKE means that the letters are formed with one stroke. A draftsman never has to go back over a line of lettering. The width of a single - stroke of a pencil is the thickness of a letter.

(smaller) 21.

LETTER FORMATION

B An alphabet of vertical capitals and numbers has been arranged in family groups in the following frames. To bring out the proportions of widths to heights, the example letters are shown against a square background with its sides divided into six parts. Some letters, such as A and T, fill the squares, that is, they are equally as wide as they are high. Others, such as H and D, are five spaces wide and six spaces high. These proportions must be learned visually, so they can be drawn without hesitation..

Study the shape of each example letter, together with the order and direction of the strokes that form it; then, practice lettering each letter in the provided spaces until its form and construction are completely familiar.

(I) 37.

LETTER AND WORD SPACING

C Study the three lines of lettering shown in Figure 21. Using the guidelines provided below the example, letter the three lines with reference to the proper spacing principles.

2

Response: 3.

The thickness of the letter is formed by a _____________ - _______________ of a pencil.

Response: 21.

To enable a draftsman to draw letters without hesitation, he must learn the letter ______________________ visually.

37.

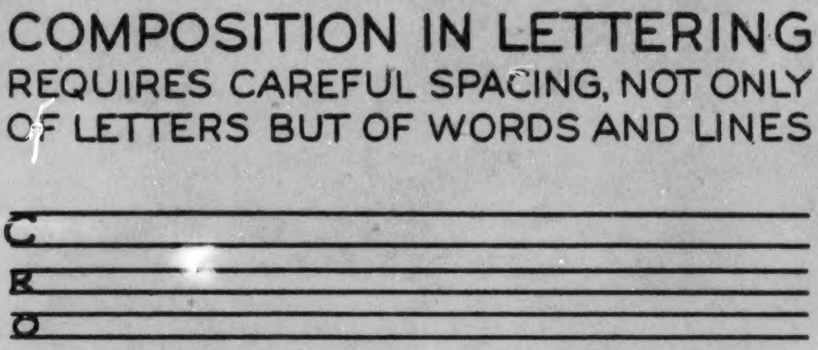

COMPOSITION IN LETTERING
REQUIRES CAREFUL SPACING, NOT ONLY
OF LETTERS BUT OF WORDS AND LINES
C
R
O

Figure 21

(single - stroke) 4.

A Lettering used on drawings must be uniform. The best method to insure uniformity is to use vertical lettering. Vertical letters are formed with lines that run straight up and down.

(proportions)

22.

I-H-T GROUP

B The letter I is the foundation stroke. It is a single line straight up and down. The letter H is nearly square (the width is 5/6 of the height), and in accordance with the rule of stability, the cross-bar is just above center. The top of the T is drawn first to the full width of the square, and the stem is started accurately, as its middle point.

Study the examples in Figure 8 and practice forming the figures in the spaces provided. Be sure to stay inside the guidelines that are shown.

---

38. (Action)

C Place a sheet of tracing paper (8½" x 11") on your drawing board with the long edge vertical. After aligning the paper with your T-square, secure it to the drafting board with masking tape. Remove the "Ames Lettering Guide" from your desk drawer and place it on the upper right corner of the drafting board. You will also need either a 5H pencil or your mechanical pencil with 5H lead, and your lead pointer. Once the above tasks are completed, proceed to the next frame.

Response: 4.

To insure uniformity in lettering, ____________________ lettering is used.

22.

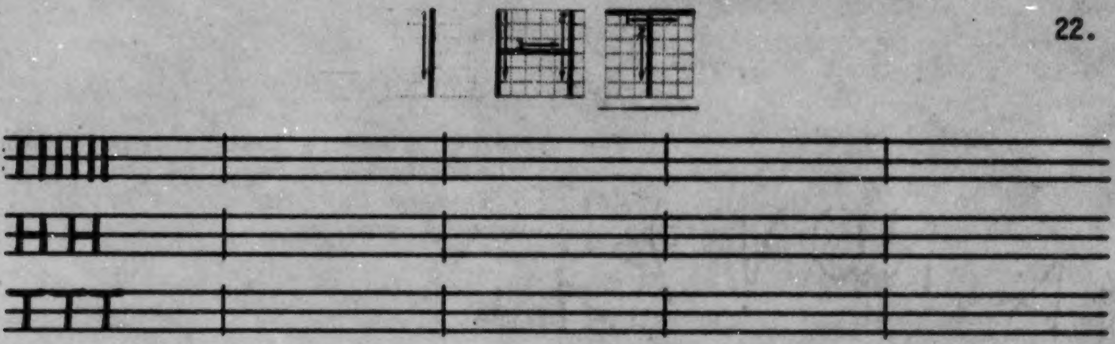


Figure 8

(vertical) 5.

A

Commercial Gothic is a fancy name for a style of lettering that simply means, "All lines used to form the letters are of the same thickness or line weight."

23.

L - E - F GROUP

B

The letter L is made with two strokes. The first two strokes of the letter E is made the same as for letter L. The letter F is made the same as the letter E, omitting the bottom stroke.

Study the examples in Figure 9. Practice forming the letters of the L-E-F Group in the practice spaces provided.

39.

GUIDELINES

C

Thusfar, guidelines have been provided for you to practice your lettering. However, you will be required to construct your own guidelines on actual drawings. Guidelines are used for ALL lettering. The "Ames Lettering Guide" will be used to construct required guidelines on ALL course drawings.

Refer to your "Ames Lettering Guide" during the next few frames, as you learn how to draw and use guidelines for lettering.

Response: 5.

Letters that have the same thickness for all lines are called ______________ ______________.

23.

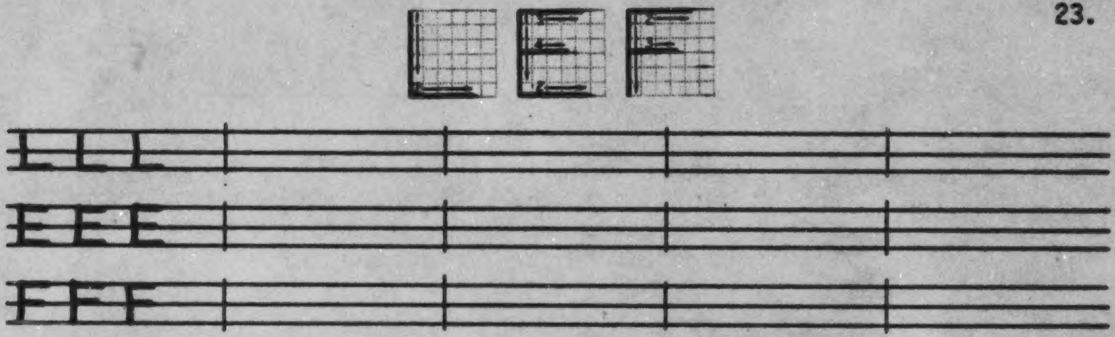


Figure 9

Response: 39.

All lettering requires the construction of ______________.

(Commercial Gothic)

6.

Letters are divided into two groups, capital and lower case. ALL LETTERING performed in this course will be accomplished, using CAPITAL LETTERS.

A

24.

N - Z - X - Y GROUP

Study the examples in Figure 10 on the facing page. Note that the letters Z and X are smaller at the top than at the bottom, in application of the "Rule of Stability." Practice letters N - Z - X - Y in the spaces provided on the facing page.

B

(guidelines)

40.

Guidelines are light lines drawn with construction line weights. Therefore, a draftsman will use a sharp, 5H pencil or lead to construct guidelines. Guidelines should be dark enough to be seen, but NOT dark enough to reproduce on a drawing print.

C

Response: 6.

________ letters will be used in this course.

24.

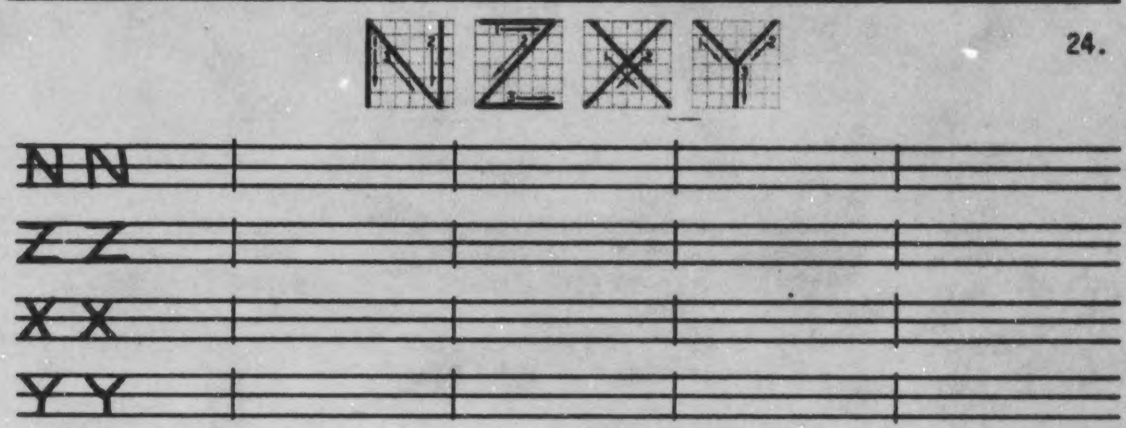

N
Z
X
Y
NN
ZZ
XX
YY

Figure 10

Response: 40.

Guidelines are drawn with a sharp, _____ pencil or lead.

(capital)

7. You have now learned the style of lettering that you will be using during this course of instruction.

25.

V - A - K - 4 GROUP

Note that the example reflecting the horizontal stroke of the letter "A" is one-third of the distance measured from the bottom. Also, note that the second and third strokes of the letter "K" are drawn perpendicular to each other. (See Figure 11)

Practice letters V - A - K - 4 in the spaces provided on the facing page.

(5H) 41.

It is possible to draw guidelines for lettering from 1/16 to 2 inches in height with the use of the "Ames Lettering Guide." The numbers 10 to 2, shown on the disc, denote the height of the letters in thirty-seconds of an inch.

Let us assume that we want to form letters 7/32 of an inch in height. Therefore, we must rotate the disc so the number 7 coincides with the frame index. The disc is rotated by holding the upper corner of the "Ames Lettering Guide" with one hand, and turning the disc with your free hand.

18

Response: 7.

The style of lettering used by draftsmen is ____________ -
________________, ______________, ____________
________________, ______________ letters.

25.

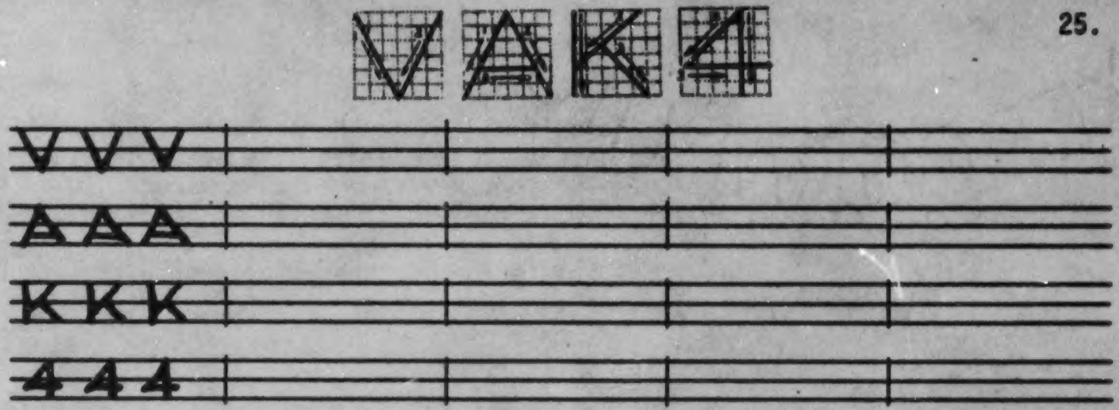

VVV
AAA
KKK
444

Figure 11

41.

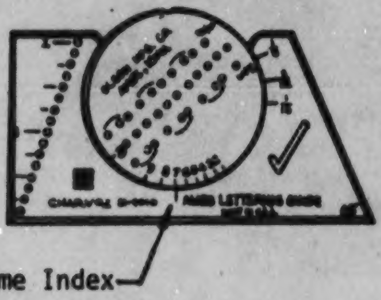

Frame Index

Figure 22

(Action) Refer to the above figure for guidance and rotate the disc until the number 7 is aligned with the frame index.

(single - stroke,
vertical, commercial
gothic, capital)

8.

A

All finished lines on a drawing are black. Lettering is a permanent or finished line. To obtain dark, permanent lettering, we will use an HB pencil.

26.

M-W GROUP

B

Refer to the examples on the facing page (Figure 12), and note that the letter M is slightly wider than it is high. The letter W is one-third wider than it is high. The letter W is the widest letter in the alphabet.

Practice forming these letters in the spaces provided on the facing page.

42.

C

The "Ames Lettering Guide" has three rows of holes on the disc. The outer two rows are labeled 2/3 and 3/5, and are used primarily for lower case letters. Since we will be forming upper case letters ONLY, the two outer rows of holes will be disregarded. Students will use ONLY the center row of holes for the construction of guidelines. The center row of holes will provide you with the necessary series of guidelines, to include the baseline, centerline and the capline. (Refer to Figure 23 for an example.)

Response: 8.

A draftsman will use an _____ pencil to obtain dark, permanent lettering.

26.

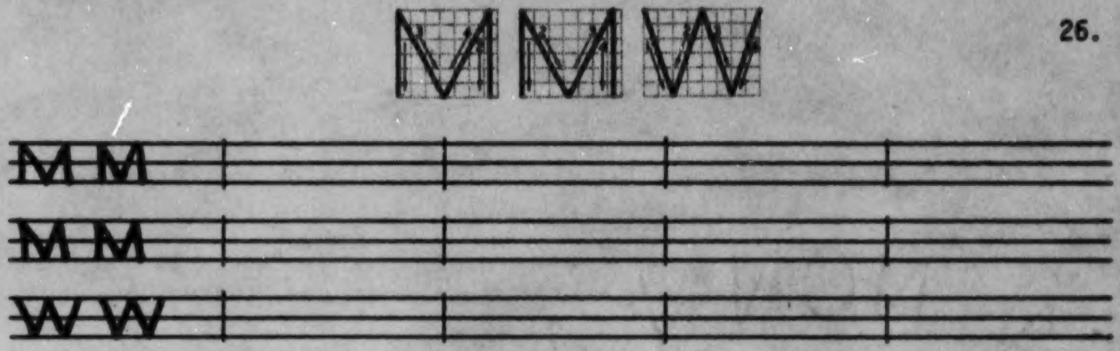


Figure 12

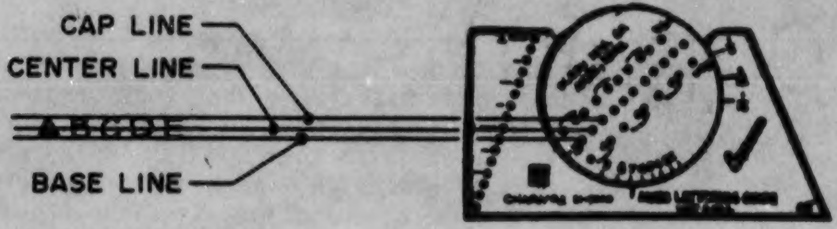

CAP LINE
CENTER LINE
ABCDE
BASE LINE

Figure 23

Response: 42.

Students will use only the ______________ row of holes on the "Ames Lettering Guide" for the construction of guidelines.

(HB) 9.

The HB pencil that we use for lettering must be sharpened to a long, conic point, which must be rounded slightly by drawing a few small circles on a sheet of scratch paper. The purpose for rounding the point is to remove any sharp edges that could tear the paper.

A

27.

O - Q - C - G GROUP

All the letters in this group are based on a circle. The circle for the letter O is drawn with two strokes.

B

Study the examples in Figure 13 and practice forming the letters in the spaces provided on the facing page.

(center) 43.

The lettering guide is used by placing the base of the guide along the edge of the T-square (or straightedge), and inserting a sharp, 5H pencil point in the bottom hole of the center row. Then, the pencil is used to pull the guide to the right as far as necessary to construct the baseline. Keeping the guide in its stopped position on the baseline, the pencil point is removed and placed in the hole above in the center row. Next, the guide is pulled to the left to construct the center guideline. Again, the pencil point is removed, and placed in the next hole (3d from the bottom). The capline is drawn by pulling the guide to the right. (Refer to Figure 24 for an example.)

C

Response:

To prevent our paper from tearing when lettering, we must _________________ the point slightly after the point has been sharpened.

27.

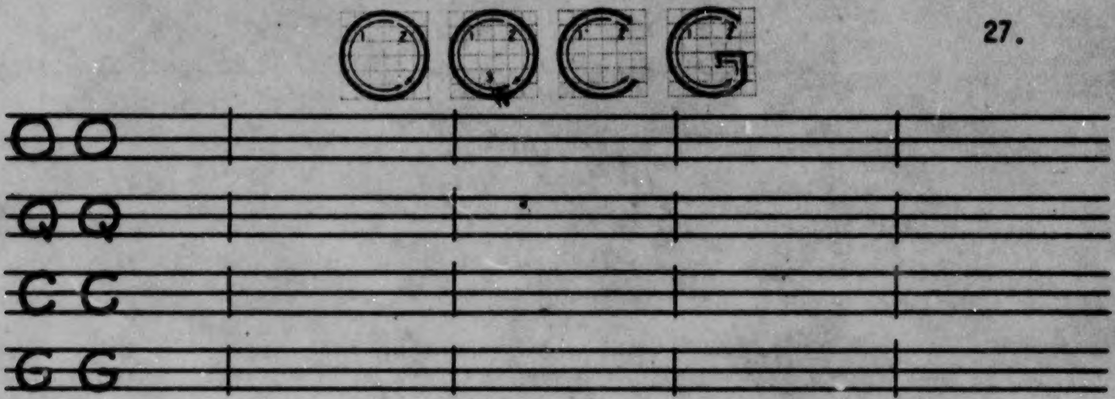


Figure 13

43.

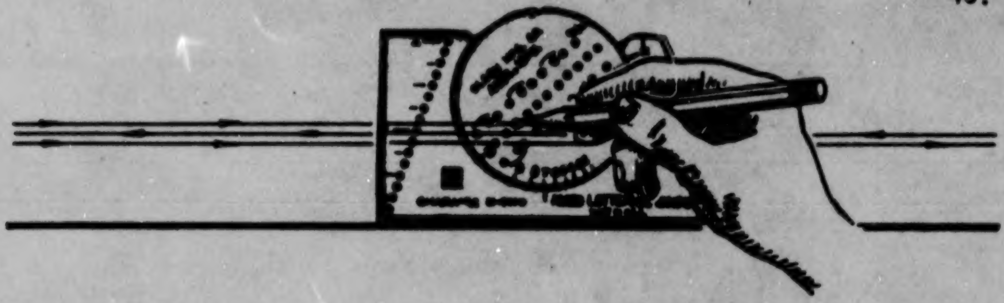


Figure 24

(Action) Draw a complete set of # 7 guidelines across the entire width of the 8½" x 11" tracing paper secured to your drawing board. The capline should be spaced approximately one inch from the top of the tracing paper.

(round) 10.

A The HB pencil must be rotated after a few strokes of lettering, so the point will remain symmetrical (balanced/rounded even).

28.

D - U - J GROUP

These letters are drawn with combinations of straight and curved strokes.

B Practice forming the letters in this group, paying particular attention to the junction points where the curved and straight lines meet. (See Figure 14)

44.

C Students will use the Number 7 size lettering for all TITLES lettered in this course.

Response: 10.

A draftsman should form a habit of ________________ his pencil after every few strokes of lettering to keep the point balanced and rounded evenly.

28.

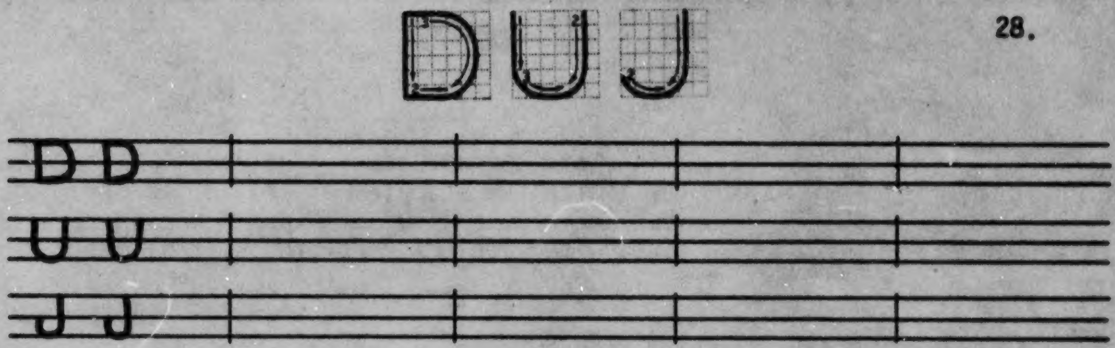


Figure 14

44.

(Action) Using the guidelines that you constructed on the tracing paper, letter the following statement (See Figure 29, page 40)

TITLES ARE ALWAYS NUMBER 7

(rotating) 11.

Utilizing a proper and comfortable position improves quality of your lettering tremendously and also enables you to letter for long periods of time without tiring.

A

PROPER POSITION

Holding the pencil correctly is the first step for attaining a proper position. The second step is using the correct finger or wrist movement to form the letters.

29.

P - R - B GROUP

B

Note the application of the " Rule of Stability " with the example of the letter B in Figure 15. The middle lines of P and R are on the centerline. The middle line of the B is slightly higher.

Refer to the facing page and practice lettering this group in the spaces provided.

45.

C

Students will use Number 5 size lettering for all SUB-TITLES required throughout this course.

Response: 11.

The first step for attaining a __________ __________ is holding the pencil correctly.

29.

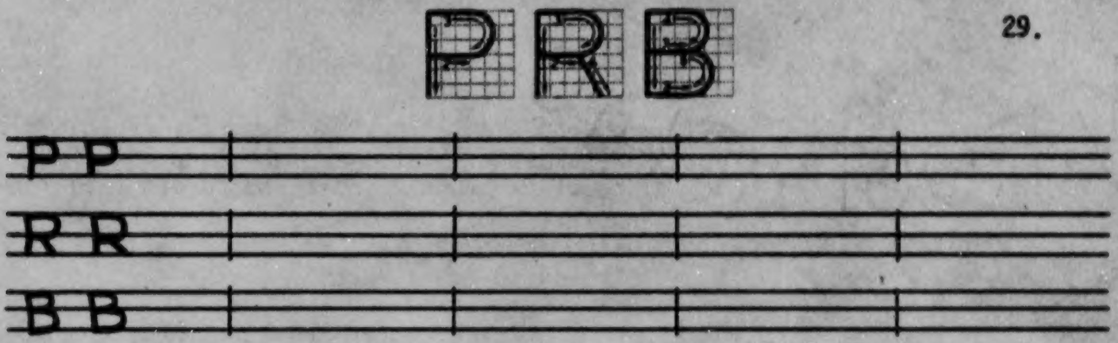


Figure 15

45.

(Action) Set your lettering guide for Number 5 size lettering. Draw a complete set of guidelines for Number 5 size lettering on your tracing paper. The capline should be spaced approximately one-half inch below the baseline of the Number 7 guidelines previously drawn.

Letter the following statement between the Number 5 guidelines (See Figure 29, page 40).

SUB-TITLES ARE ALWAYS NUMBER 5

(proper position) 12.

A

The pencil is held with the thumb, forefinger, and second finger. The third and fourth fingers rest on the paper, but DO NOT hold the pencil.

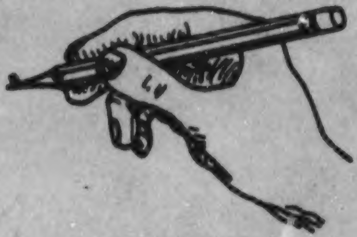


Figure 1

30.

S - 8 - 3 GROUP

B

The letters and numerals in this group are closely related in form, and the "Rule of Stability" must be observed carefully. The numeral 8 may be made on the S construction using three strokes, or by adding two more strokes to the numeral 3 (See Figure 16).

Practice forming the characters of this group in the spaces provided on the facing page.

46.

C

ALL LETTERING (other than titles and sub-titles) will be accomplished with Number 4 size lettering throughout the remainder of this course.

Response: 12.

The thumb, forefinger, and second finger are used to __________ the pencil.

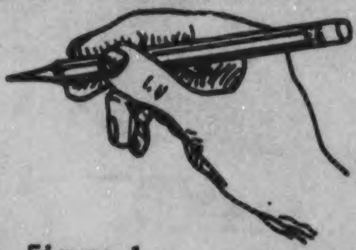


Figure 1

30.

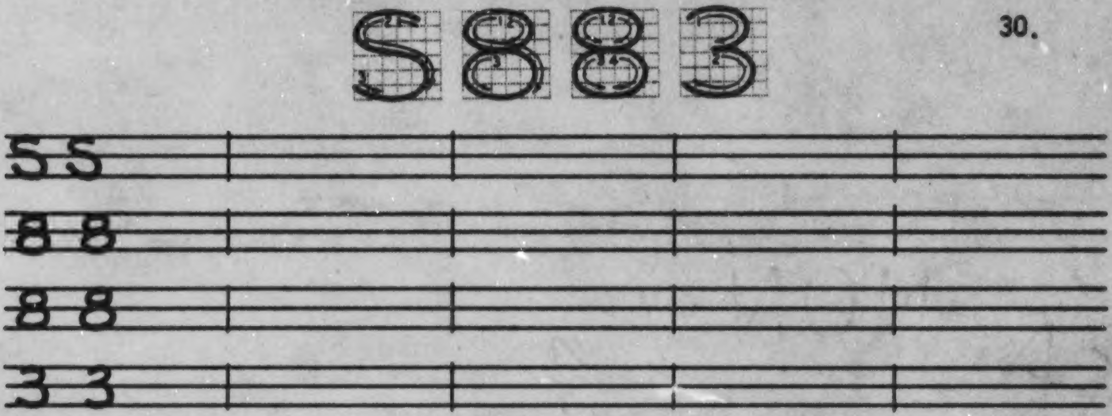


Figure 16

(Action) 46.

Set your lettering guide for Number 4 size lettering and draw a complete set of guidelines for Number 4 size lettering on your tracing paper. The capline should be spaced approximately one-half inch below the baseline of the Number 5 guidelines previously drawn.

Letter the following statement, using the Number 4 size guidelines (See Figure 29, page 40).

SCALE, DIMENSIONS AND NOTES ARE NUMBER 4 (hold) 13.

A

Vertical, slanting, and curved strokes are drawn with a steady, even FINGER movement. This is accomplished by using the holding fingers only, with NO movement of the wrist. The third and fourth fingers are used to support the hand on the paper only.

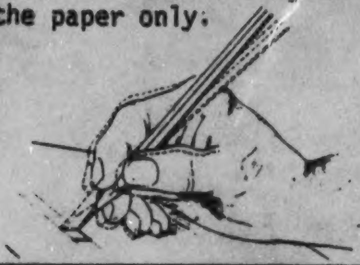


Figure 2

31.

B

NUMERALS 0 - 6 - 9 GROUP

There is a distinct difference between the letter O and the numeral 0. Note the width of the example shown in Figure 17 on the facing page. The numeral 0 is 5/6 as wide as it is high. Your attention is recalled to Frame 27, which explained that the letter O is equally as wide as it is high.

All the numbers in this group are to be drawn as 5/6 as wide as they are high. Practice forming these numbers in the provided spaces on the facing page.

47.

C

The spacing between a set of guidelines will always be the same as the lettering size. This will permit you to draw the guidelines for all lettering and spacing at the same time.

Response: 13.

__________movement is used to form vertical, slanting and curved strokes.

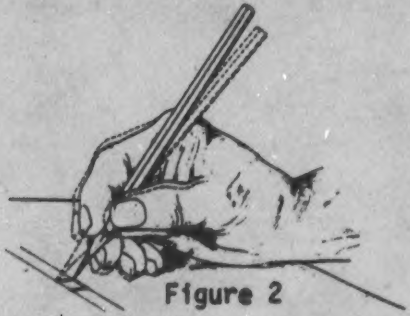


Figure 2

31.

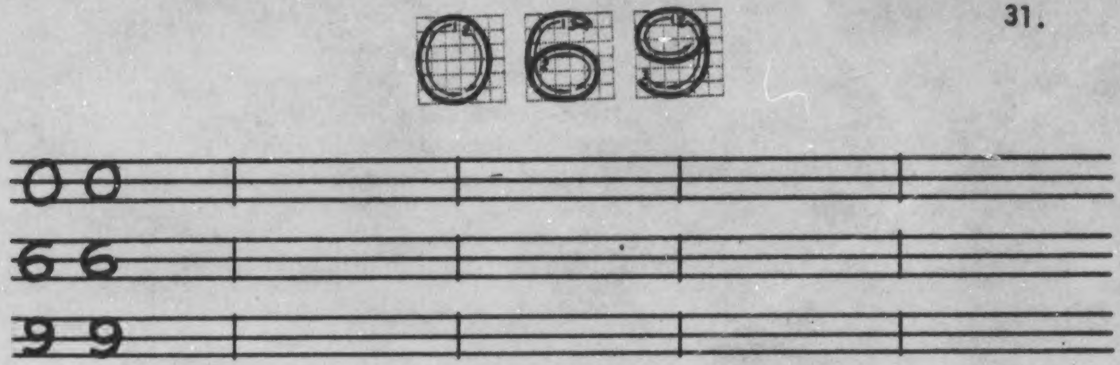


Figure 17

(Action) 47.

Draw a series of guidelines for two lines of Number 4 size lettering. Your spacing between the rows of guidelines will be the same size as your letters. (Refer to Figure 29, page 40 when constructing your guidelines, and letter the statements shown in spaces.)

(Finger)

14.

A Horizontal strokes are made similar to vertical strokes, BUT there is some pivoting of the hand at the wrist.

32.

2 - 5 - 7 GROUP

B Note the " Rule of Stability " as applied to the examples shown in Figure 18. All the numbers in this group are drawn 5/6 as wide as they are high.

Practice forming these numbers in the spaces provided on the facing page.

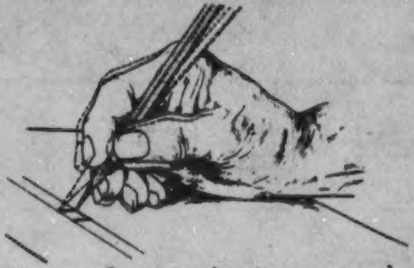
48.

FRACTIONS

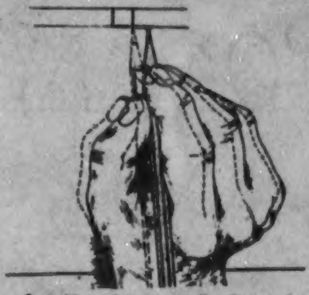
C Guidelines are always used for lettering fractions, with the total height of the fraction twice the size of the whole number (See Figure 25).

Response: 14.

Study Figures 3 and 4. Notice how the movements differ for vertical and horizontal strokes.



(Figure 3, Vertical Strokes)



(Figure 4, Horizontal Strokes)

32.

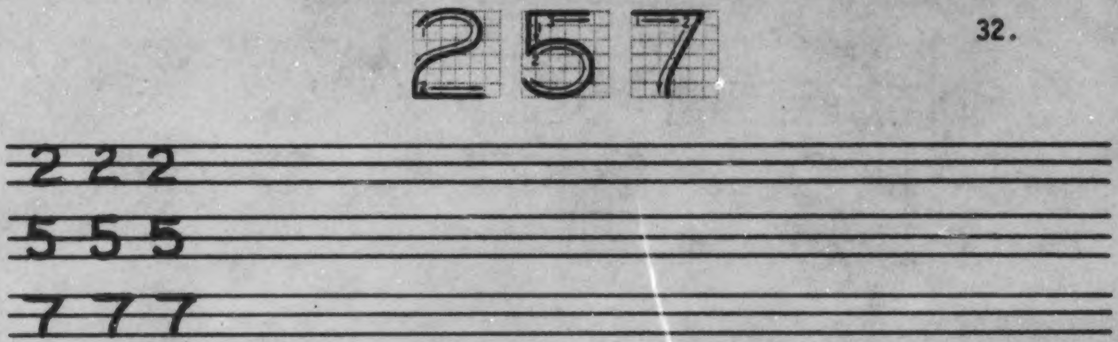

257
2 2 2
5 5 5
7 7 7

Figure 18

48.

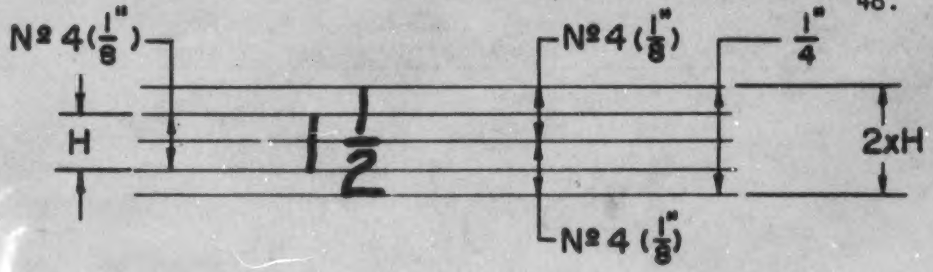
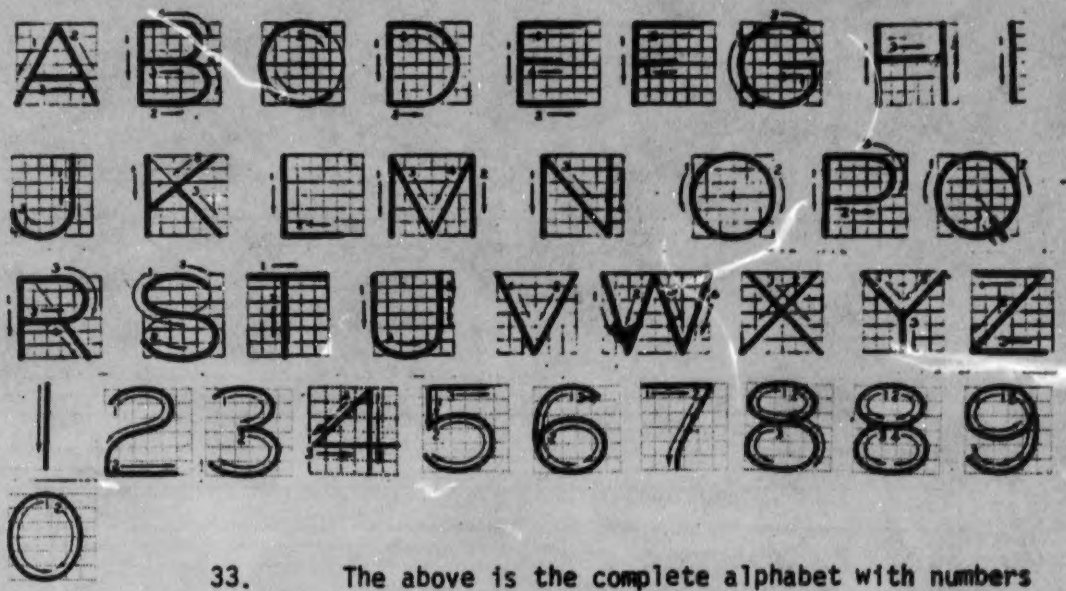

Nº 4(1/8")
H
1 1/2
Nº4(1/8")
1/4"
2xH
Nº 4 (1/8")

Figure 25

15.

A

Vertical strokes are made entirely by finger movement. Horizontal strokes are made by pivoting the whole hand at the wrist; fingers move slightly to keep the stroke perfectly horizontal.



33.

The above is the complete alphabet with numbers showing you once again how the letters and numbers are formed with the proper stroke order.

B

Using the guidelines on the facing page, letter the alphabet with numbers. Refer to the examples above to insure use of the proper stroke order.

49.

C

Fractions are always made with a horizontal bar. Be careful to leave a clear space above and below this horizontal bar (See Figure 26).

Response: 15.

Vertical, slanting, and curved strokes are drawn with a ________________ movement only.

Horizontal strokes require some pivoting at the ________.

33.

49.

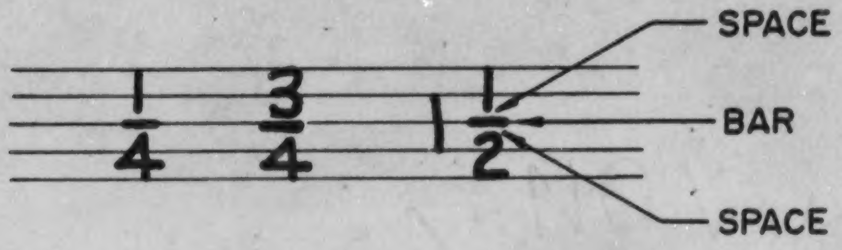

1/4
3/4
1/2
SPACE
BAR
SPACE

Figure 26

(finger, wrist) 16.

STROKE ORDER AND DIRECTION

To make each repetition of each letter appear the same, a draftsman must develop a consistent habit of stroke order and direction.

A

In the following frames, the acceptable sequence and stroke direction are given for right-handers. If you are left-handed, it may be more suitable for you to at least reverse the horizontal stroke direction.

34.

COMPOSITION

B

Proper spacing of letters and words contribute equally as much as the letter forms for the appearance of a block of lettering. The spacing between letters and words is called composition.

50.

C

Guidelines for fractions are easily obtained with your lettering guide. Five holes on the middle row must be used to obtain whole numbers with fractions. The third hole will represent the middle of the fraction. Study Figure 27, and note the use of the guidelines.

Response: 16.

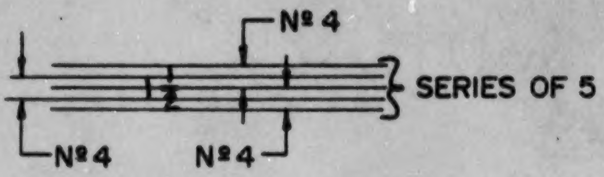
A draftsman must develop a consistent habit of stroke ________________ and ________________ to make repetitions of each letter appear identical.

Response: 34.

The appearance of a block of lettering is enhanced by the forms of letters and ________________ ________________.

NOW, TURN BACK TO PAGE 4, CHECK YOUR RESPONSE,
AND PROCEED WITH FRAME 35.

50.



ALL FRACTIONS REQUIRE A TOTAL OF
5 GUIDELINES

Figure 27

(order, direction)

17. (Action)

LETTER STROKES

A

On the guidelines provided in Figure 5, practice vertical and horizontal strokes by repeating stroke patterns as shown. Be sure to employ the correct position and insure that you use sufficient pressure to obtain black lines. Strokes must be made in the direction of the arrows shown in the illustration.

51.

C

On the guidelines provided in Figure 28, practice lettering fractions by repeating the numbers shown in the upper line.

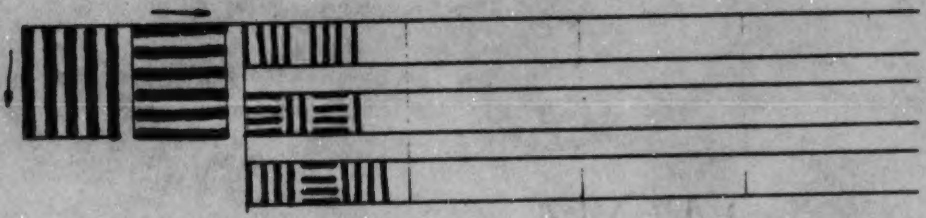


Figure 5

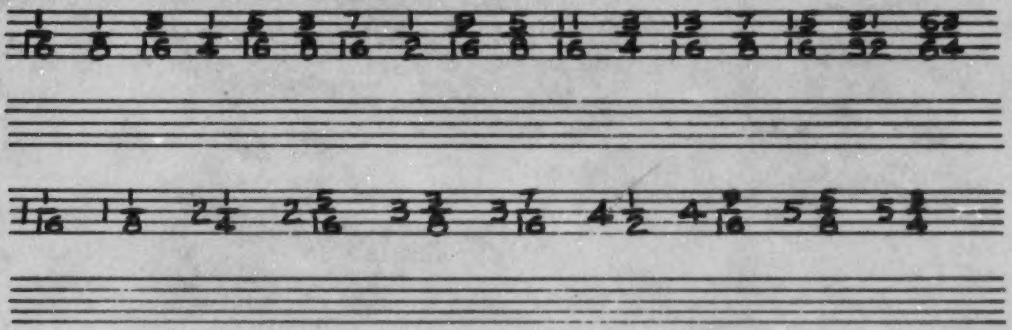

1/16 1/8 3/16 1/4 5/16 3/8 7/16 1/2 9/16 5/8 11/16 3/4 13/16 7/8 15/16 31/32 63/64
1 1/16 1 1/8 2 1/4 2 5/16 3 3/8 3 7/16 4 1/2 4 9/16 5 5/8 5 3/4

Figure 28

18. (Action)

A Using the guidelines provided in Figure 6, practice left and right slope strokes by repeating stroke patterns as shown.

52.

C Complete the lettering exercise on your tracing paper by lettering the statements shown on Figure 29. Be sure to use the letter size as noted on the left margin of the figure. (DO NOT letter the size numbers.)

18.

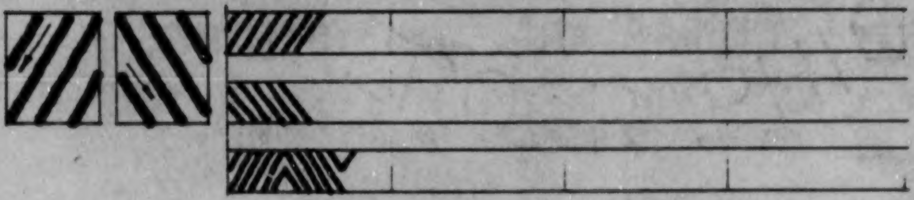
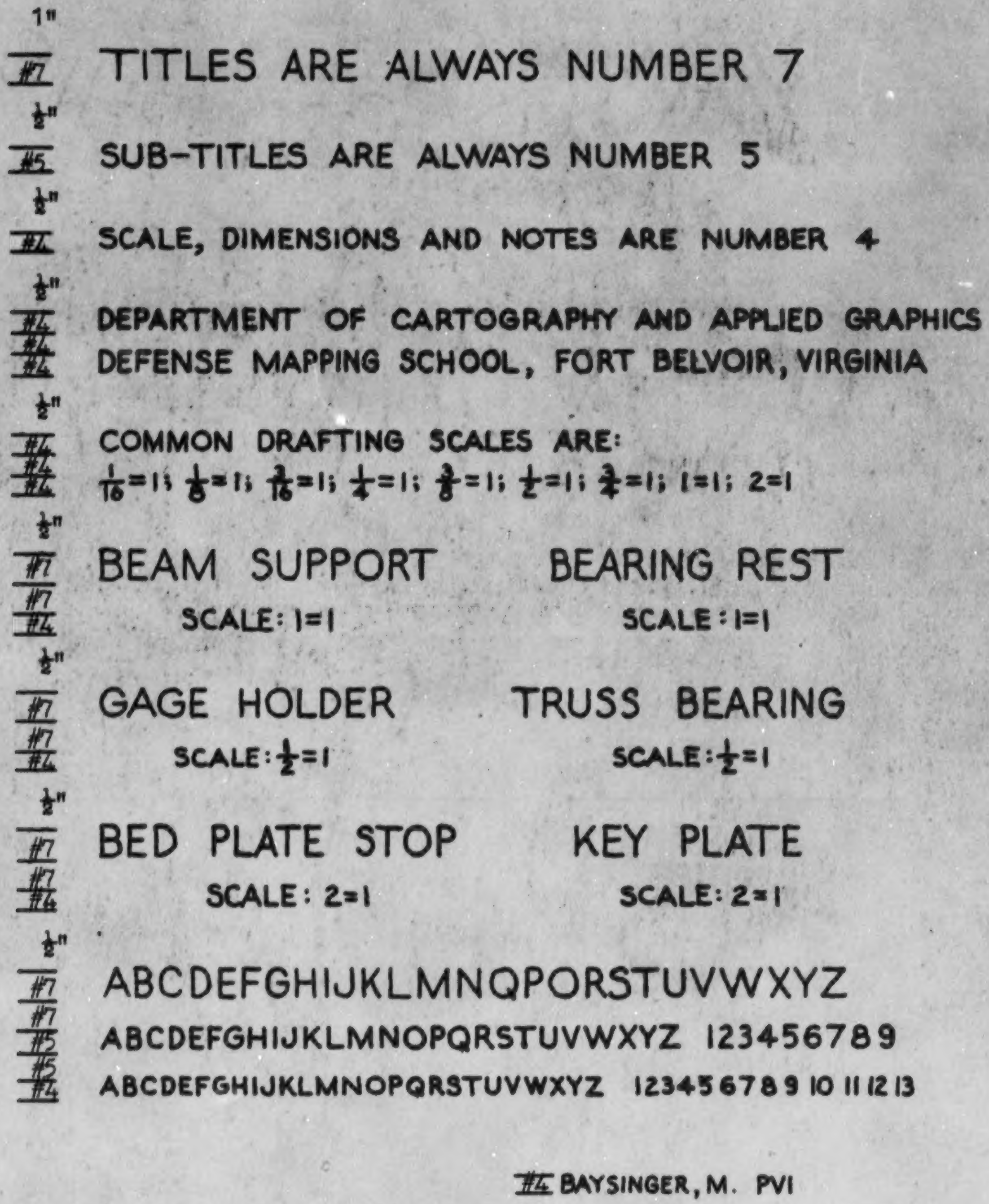


Figure 6

YOU HAVE NOW COMPLETED LEVEL A. TURN BACK TO PAGE 4, AND CONTINUE WITH FRAME 19, LEVEL B.

TURN TO FIGURE 29, PAGE 40, AND COMPLETE THE LETTERING EXERCISE ON YOUR TRACING PAPER.



1"

#7 TITLES ARE ALWAYS NUMBER 7

½"

#5 SUB-TITLES ARE ALWAYS NUMBER 5

½"

#4 SCALE, DIMENSIONS AND NOTES ARE NUMBER 4

½"

#4 DEPARTMENT OF CARTOGRAPHY AND APPLIED GRAPHICS
#4
#4 DEFENSE MAPPING SCHOOL, FORT BELVOIR, VIRGINIA

½"

#4 COMMON DRAFTING SCALES ARE:
#4
#4 $\frac{1}{16}=1$; $\frac{1}{8}=1$; $\frac{3}{16}=1$; $\frac{1}{4}=1$; $\frac{3}{8}=1$; $\frac{1}{2}=1$; $\frac{3}{4}=1$; $1=1$; $2=1$

½"

#7 BEAM SUPPORT BEARING REST
#7
#4 SCALE: 1=1 SCALE: 1=1

½"

#7 GAGE HOLDER TRUSS BEARING
#7
#4 SCALE: ½=1 SCALE: ½=1

½"

#7 BED PLATE STOP KEY PLATE
#7
#4 SCALE: 2=1 SCALE: 2=1

½"

#7 ABCDEFGHIJKLMNQPORSTUVWXYZ
#7
#5 ABCDEFGHIJKLMNOPQRSTUVWXYZ 123456789
#5
#4 ABCDEFGHIJKLMNOPQRSTUVWXYZ 12345 6789 10 11 12 13

#4 BAYSINGER, M. PVI

Figure 29

INTRODUCTION

The purpose of this booklet is to furnish students the opportunity to broaden (or refresh) their knowledge of basic mathematics. It is a workbook and is not written to teach, but rather to afford the opportunity to practice calculations and operations in mathematics which may have been forgotten or require refreshing.

The booklet is referenced to the Defense Mapping School text, "Comprehensive Review of Mathematics" (ST 003), and certain sections have been expanded where additional information was deemed necessary.

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BASIC ARITHMETIC

1. ADDITION, SUBTRACTION, MULTIPLICATION AND DIVISION

a. Add the following:

(1) 7642 + 698
(2) 1794 + 15 + 379
(3) 1274 + 673 + 1989 + 2001 + 12 + 5
(4) 10792 + 1798 + 203222
(5) 194002 + 18332 + 157

b. Perform the following subtractions:

(1) 222796 - 198999
(2) 15798 - 13989
(3) 27654 - 25765
(4) 391234 - 387345
(5) 192123 - 187345

c. Work the following problems:

(1) A construction company, using five trucks, hauled the following loads of soil from a road construction site. 3t, 5t, 2t, 3t, 4t, 1t, 4t, 2t, 3t, 3t, 2t, 2t, 3t, 5t, 5t, 4t, 3t, 3t, 2t, 2t, 5t, 5t. How many tons of soil were moved?

(2) From the sum of 2732, 19237, 32432 and 79456 subtract the sum of 35678, 4567, 7890 and 2765.

2. COMMON FRACTIONS (Reference: CRM Text, Section II, para 11-17)

a. As discussed in above reference, addition and/or subtraction of common fractions requires reduction of all fractions to their LOWEST COMMON DENOMINATOR (LCD). If a relatively large number of fractions are involved, the determination of the LCD cannot be accomplished by inspection. Following is a method of determining the LCD.

b. Let us assume that six fractions with denominators of 18, 32, 7, 21, 80 and 28 are to be added. Set up this problem as follows:

	18	32	7	21	80	28
2	9	16	7	21	40	14
3	3	16	7	7	40	14
7	3	16	1	1	40	2
2	3	8	1	1	20	1
2	3	4	1	1	10	1
2	3	2	1	1	5	1

What we have done here is this: we factored out common factors of two or more numbers. That is, we divided each number divisible by two, writing the 2 on the left of the vertical line, and the number of times it went into the horizontal number under such number. We also copied numbers not divisible by 2 on this horizontal line. Then we did the same thing with 3, 7, etc. until no common factors remained. The LCD (or Lowest Common Multiple (LCM)) is then found by multiplying the common factors down on the left and multiplying these by the numbers across the bottom horizontal line. Our LCD then would be 2 x 3 x 7 x 2 x 2 x 2 x 3 x 2 x 1 x 1 x 5 x 1 or 10080.

c. Determine LCD and solve the following problems:

(1) 1/4 + 3/8 + 1/2 + 3/4 + 3/8
(2) 3/16 + 3/4 + 1/2 + 1/4 + 3/8
(3) 3/32 + 3/8 + 15/16 + 5/8
(4) 51/64 + 29/32 + 5/8 + 7/8
(5) 21/64 + 31/32 + 5/16 + 9/16 + 3/4
(6) 1/5 + 24/25 + 2/3 + 9/5 + 14/15
(7) 1/3 + 8/9 + 26/27 + 2/3 + 7/9
(8) 1/8 + 3/8 + 7/8 + 3/4 + 13/16
(9) 15/17 + 1/2 + 3/4
(10) 21/22 + 3/11 + 3/4 + 7/11
(11) 4 1/2 + 3 7/8 + 3/4 + 2 1/8 .
(12) 12 7/8 + 3 3/4 + 11 31/32 + 12 1/2
(13) 12 7/8 + 4 7/8 - 10 3/4 - 5 7/8
(14) 11 19/32 + 12 9/16 - 5 5/8 - 6 13/32
(15) 2 2/3 + 6 4/5 + 7 7/12 + 8 17/20 + 3 4/7 - 25 17/21
(16) 3/4 x 7/8
(17) 5/8 x 7/8 x 1/2 x 2/21
(18) $\frac{3 \times 4 \times 6 \times 7}{8 \times 9 \times 12 \times 3}$
(19) 5 1/2 x 10 3/4 x 4 7/8
(20) 21 15/16 x 5 4/7 x 11
(21) 1/2 ÷ 2/3
(22) 3/16 ÷ 9/8

(23) 1 5/8 ÷ 3/4
(24) 21 7/8 ÷ 15/8
(25) 27 1/2 ÷ 1/4
(26) (3/4 x 4/8 x 1/2) ÷ 1/2
(27) (5/16 x 1/2 x 8/9) ÷ (1/2 x 3/4)
(28) (3/32 x 8/9 x 3/4) ÷ (2/3 x 3/4)
(29) (1 7/8 x 2 1/4) ÷ 1/8
(30) (3 3/32 x 6 8/9) ÷ 7/8

3. DECIMAL FRACTIONS (Reference: CRM Text, Section II, para 18-26)

a. Remember these rules of thumb:

(1) To reduce a common fraction to a decimal fraction merely divide the denominator into the numerator.

(2) When adding or subtracting decimal fractions make sure the decimal points are lined up vertically.

(3) In multiplication, multiply fractions as whole numbers and on the product count off, from right to left, the sum of the decimal places in multiplier and multiplicand.

(4) In division, change the divisor into a whole number (removal of decimal point) by multiplying the divisor by 10, or a multiple thereof, and also multiplying the dividend by the same number.

b. Problems.

(1) Change the following common fractions into decimal fractions.

(a) 3/8, 5/8, 7/8
(b) 3/10, 3/100, 3/1000
(c) 1/4, 1/2, 3/4
(d) 1/5, 2/5, 3/5, 4/5
(e) 3/7, 2/9, 10/11, 15/16
(f) 1 12/13, 2 7/8, 13 12/25, 100 3/4
(g) 25 15/16, 37 3/8, 12 11/32
(h) 15 7/15, 28 112/625, 19 117/227
(i) 27 27/27, 212 15/75, 115 111/333
(j) 127 2/3, 184 5/8

(2) Change the following decimal fractions to common fractions (proper or improper)

(a) 1.625, 3.75, 16.875
(b) 0.5, 0.50, 0.6667
(c) 3.125, 1.678, 2.556
(d) 127.333, 12.422, 1.89
(e) 11.675, 14.321, 11.123

(3) Add the following decimal fractions.

(a) 127.321, 11.40, 159.3, 227.3456, 0.01
(b) 12.4, 13.7214, 150, 162.875
(c) 1.002, 114.1, 275.75, 0.008
(d) 1756.321, 2706.41, 36.34567, 1.12
(e) 1576.127, 35333.33, 1.001, 0.0001

(4) Perform the following subtractions:

(a) 1736.3941 - 169.01
(b) 975.875 - 12.1
(c) 1394.667 - 0.0008
(d) 427.333 - 400.03
(e) 1242.345 - 1080.5

(5) Solve the following problems:

(a) $\frac{3.68 \times 24.24 \times 100}{24 \times 25 \times 11.04}$ (to 3 decimal places)

(b) Add $\frac{3\ 2/5}{3\ 4/10}$ and $\frac{2\ 3/4}{4\ 1/8}$ then divide the sum by 1 11/12, and change the result to a decimal fraction (to 5 decimals).

4. POWERS AND ROOTS. (Reference: CRM, Section VI, para 38-44.)

a. Fractional Exponents: Any number may be raised to a fractional power, such as 1/2, 1/3, 3/32, 2/5 etc, etc. It is a different way of writing the expression, using the radical sign. For instance: 2 to the 1/2 power may be written as $\sqrt[2]{2}$, and

$2^{3/32} = \sqrt[32]{2^3}$ that is:

In fractional exponents the numerator of the fraction is the power to which the number is raised and the denominator is the index of the root.

b. Negative Exponents: Negative exponents indicate that the expression is a fraction in itself and stands for "1" divided by the expression. For instance:

$$12^{-2} = \frac{1}{12^2} = \frac{1}{144} \qquad \text{and } 15^{-3/4} = \frac{1}{\sqrt[4]{15^3}}$$

Numbers with the same base are multiplied by the addition of their exponents. They are divided by subtracting exponents. They are raised to a certain power by multiplying their exponents and have a root extracted by dividing their exponents.

Thus:

$$a^3 \times a^5 = a^{3+5} = a^8$$

$$a^6 \div a^3 = a^{6-3} = a^3$$

$$(a^2)^3 = a^{2\times 3} = a^6$$

$$\sqrt[3]{a^6} = a^{6/3} = a^2$$

c. Problems.

(1) Find the square of:

(a) 72, 19, 28, 14
(b) 12, 9, 17, 16
(c) 15, 125, 75, 50
(d) 1537
(e) 234

(2) Find the cube of:

(a) 3, 6, 19, 12
(b) 2, 4, 7, 8
(c) 37
(d) 565
(e) 127

(3) Extract, long hand, to two decimal places the square root of:

(a) 36481
(b) 93636
(c) 534361
(d) 125.44
(e) 866761

5. RATIO AND PROPORTION (Reference: CRM, Section V, para 34 - 37)

a. Problems.

(1) Find the values of the following ratios.

(a) 7/2
(b) 3:1
(c) 15:7 1/2
(d) 18:17
(e) 7/8

(2) Divide $100 between A and B in the ratio of 3:7.

(3) Fifty-one students entered a class. 33 of them finished the course. What is the ratio of the number who finished to the number who entered the class?

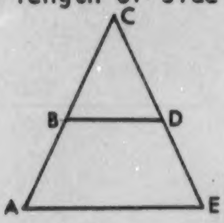
(4) What are the inverse ratios of:

$$2/7,\ \frac{3\ 1/2}{9},\ \frac{10\text{ feet}}{50\text{ feet}},\ \frac{22\ 1/2}{2\ 4/5}$$

(5) A road bed rises 2.5 feet in 200 feet. What is the grade? (Grade = rise or fall per 100 feet)

(6) The scale on a highway map is given as 1 1/2" = 10 miles. A motorist wishing to travel between two towns measures the distance on the map as 8 3/4". What is the ground distance between the two towns?

(7) In triangle ACE, AB = 150 feet, BC = 300 feet, CD = 300 feet, DB = 200 feet. Find length of side AE.



(8) If a rod 4 feet long casts a shadow 7 feet long, what is the height of a building which, at the same time, casts a shadow of 198 feet?

(9) A level party does 30 miles of level line in 15 days by working 4 hours a day. If this same party had worked 6 hours a day, how long would it have taken to do the same job?

6. PERCENTAGES

a. Definition. Percentage is the process of computation in which the basis of comparison is a hundred. The term per cent--from per, by, and centum, hundred -- means by or on the hundred. Thus, 2 per cent of a quantity means 2 parts of every hundred parts of the quantity.

b. Symbol. The symbol of percentage is %. Per cent may also be indicated by a common fraction or a decimal. Thus, 5% = 5/100 = .05.

c. Base, Rate, and Percentage.

(1) The base is the number on which the percentage is computed.

(2) The rate is the number of hundredths of the base to be taken.

(3) The percentage is the portion of the base determined by the rate.

d. Conversion of Decimal to Per Cent. To change a decimal to per cent, move the decimal point two places to the right and add the per cent symbol.

EXAMPLE: Change .375 to per cent:
Move decimal point two places to right: 37.5
Add per cent symbol: 37.5%

e. Conversion of Fraction to Per Cent. To convert a fraction to per cent, divide the numerator by the denominator. Then, convert the decimal to per cent.

EXAMPLE: Change the fraction 5/8 to per cent:
Divide numerator by denominator: 5 ÷ 8 = .625
Convert decimal to per cent: .625 = 62.5%
Thus, 5/8 = 62.5%

f. Conversion of Per Cent to Decimal. To change a per cent to a decimal, omit the per cent symbol and move the decimal point two places to the left.

EXAMPLE: Change 15% to a decimal:
Omit per cent symbol: 15% = 15
Move decimal point two places to left: 15 = .15
Thus, 15% = .15

g. Conversion of Per Cent to Fraction. To change a per cent to a fraction, first change the per cent to a decimal and then to a fraction. Reduce the fraction to its lowest terms.

EXAMPLE: Change 25% to a fraction:
Change to a decimal: 25% =.25
Change to a fraction: .25 = 25/100
Reduce fraction to lowest terms: 25/100 = 1/4
Thus, 25% = 1/4

h. Finding Percentage.

(1) General. To find the per cent of a number, write the per cent as a decimal and multiply the number by this decimal. In this case, the base and rate are given. The problem is to find the percentage.

EXAMPLE 1: Find 5% of 140 (140 is the base, 5% is the rate, and the product is the percentage):

5% of 140 = .05 x 140 = 7

EXAMPLE 2: Find 5.2% of 140:

5.2% of 140 = .052 x 140 = 7.28

(2) Solve the following:

(a) Find the relative error for a limit of error of .05 inch in measuring 24.2 inches.

(b) Find the relative error for a limit of error of 2 inches in measuring 200 yards.

(c) A generator is rated at 2,000 watts with a maximum output of 2,100 watts. What is the per cent of overload capacity?

(3) Finding Per Cent Greater than 100 Per Cent. To change a per cent larger than 100 per cent to a decimal, move the decimal point two places to the left as with percentages smaller than 100 per cent.

EXAMPLE: 75% of a number is .75 times the number
100% of a number is 1.00 times the number
150% of a number is 1.50 times the number
325% of a number is 3.25 times the number

(4) Finding Per Cent Smaller Than 1 Per Cent. To find a part of 1 per cent, first find one whole per cent of a number and

then determine the part called for.

EXAMPLE 1: Find 1/2% of 840:
1% of 840 = 8.40
1/2 of 8.40 = 4.20
Thus, 1/2% of 840 = 4.20

EXAMPLE 2: Find 3/5% of 15:
1% of 15% = .15
3/5 of .15 = .09
Thus, 3/5% of 15 = .09

i. Finding Rate. To find what per cent one number is of another, write the problem as a fraction, change the fraction to a decimal, and write the decimal as a per cent. In this case, the percentage and base are given. The problem is to find the rate.

EXAMPLE 1: 3 is what per cent of 8? (3 is the percentage, 8 is the base, and the quotient is the rate.)

3/8 = .375
.375 = 37 1/2%
Therefore, 3 is 37 1/2% of 8

EXAMPLE 2: What per cent of 542 is 234?

234/542 = .4317 + (round off)
.432 = 43.2%
Therefore 234 is 43.2% of 542

EXAMPLE 3: 125 is what per cent of 50?

125/50 = 2.50
2.50 = 250%
Therefore, 125 is 250% of 50

j. Finding Base Numbers. To find a number when a per cent of the number is known, first find 1% of the number, then find 100% of the number. In this case, the percentage of the whole number and the rate are given. The problem is to find the base.

EXAMPLE 1: 42 is 12% of what number?

12% (base number) = 42
1% (base number) = 42/12 = 3.50
100% (base number) = 100 x 3.50 = 350
Therefore the base number is 350

EXAMPLE 2: 45 is 150% of what number?

150% (base number) = 45
1% (base number) = 45/150 = .3
100% (base number) = 100 x .3 = 30
Therefore the base number is 30

(1) Numerical Problems. (Express in %)

(a) 1/5
(b) 1/4
(c) 1/3
(d) 3/4
(e) .25
(f) .765
(g) .608
(h) 2.24

(2) Your company is building 24 miles of road. What per cent completed are you when:

(a) 7 miles are completed.
(b) 3 miles are completed.
(c) 15 miles are completed.
(d) 21 miles are completed.

(3) Verbal Problems.

(a) A construction company has poured 360 cubic yards of concrete; if this is 25% of the total amount to be poured, how many cubic yards will be required to complete the job?

(b) A company contains 136 men. If this is 80% of the T/O strength, what is the total strength of the company?

(c) Your unit uses 460 gallons of gasoline a month. You are ordered to reduce that by 20%. How much gas can you draw next month?

(d) There are 180 men in your unit. You must send 15% of them on special detail. How many men will you send?

(e) If solid rock expands upon blasting by 90%, how many cubic yards of loose rock will a solid rock of 180 cubic yards give?

(f) If you spend 48 hours out of 960 hours on mathematics, what percent of your time do you spend on mathematics?

7. THE METRIC SYSTEM WITH CONVERSION TABLES (Reference: CRM, Section IV, Para 27 - 33)

a. Most of the countries of the world, except the United States, have converted to the Metric System of measurement. Therefore, when working in these countries, we must be familiar with and be able to proficiently use this system.

b. Let us first review the metric system of temperature measurement. The freezing point of water is 32° Fahrenheit (F) in the English System and we know that water boils at 212°F. When using the Metric System, we see that the freezing point is 0° Celsius (C) and the boiling point is 100°C.

c. To change from one system to the other, the following formulas may be used:

(1) To convert from Fahrenheit to Celsius:
$C^{\circ} = 5/9\ (F^{\circ} - 32)$
(2) To convert from Celsius to Fahrenheit:
$F^{\circ} = (9/5\ C^{\circ}) + 32$

d. The basic unit names of the various types of measurements are as follows:

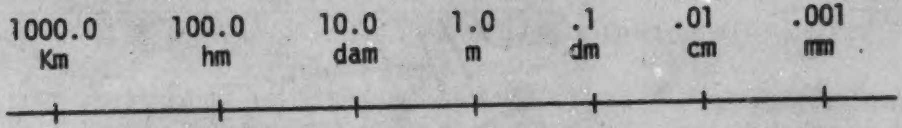
Length: Meter (m)
Volume: Cubic meter (m^3)
Area: Square meter (m^2)
Weight: Gram (g)

e. The following prefixes, in combination with the basic unit names, provide the multiples and submultiples in the Metric System.

10^{-3}	milli	(m)	10	deka	(da)
10^{-2}	centi	(c)	10^{2}	hecto	(h)
10^{-1}	deci	(d)	10^{3}	kilo	(k)

f. Therefore, the unit name "meter", with the prefix "kilo" added, produces "kilometer", meaning "1000 meters". Or, 1 Km = 1000m. If "meter" is preceded by the prefix "milli," the result is the common term "millimeter" (mm) which is one thousandth of a meter. (.001m.)

g. The simplicity of the metric system is due to the fact that it is based upon a decimal arrangement and, regardless of the type of measurement, there is only one basic unit - the meter. We can refer to the following graph to keep us straight:



(If we convert meters to decimeters, we move 1 division to the right (multiply by 10) or move the decimal point 1 place to the right. If m to cm: 2 division or 2 places to the right. If m to hm: 2 division or 2 places to the left (or 1m = 0.01hm)

The metric measurements in most common use are shown in the following tables:

Length

10 millimeters = 1 centimeter
10 centimeters = 1 decimeter
10 decimeters = 1 meter
1000 meters = 1 kilometer

Mass

1000 milligrams = 1 gram
1000 grams = 1 kilogram
1000 kilograms = 1 metric ton

Volume

1000 cubic centimeters = 1 liter
1000 liters = 1 cubic meter

h. The following conversion tables are a great help in converting from one system to the other:

CONVERSION FACTORS

LENGTH OR DISTANCE

UNITS	CENTIMETERS	METERS	KILOMETERS	INCHES	FEET	YARDS	MILES
Centimeter	1	.01	.00001	0.3937	0.0328084	0.0109361	.0000062137
Meter	100	1	.001	39.37	3.28084	1.093613	.00062137
Kilometer	100000	1000	1	39370.	3280.84	1093.613	0.6213711
Inch	2.54	0.0254	0.0000254	1	0.08333	0.0277778	.000015783
Foot	30.48	0.3048	0.0003048	12	1	.333333	.000189394
Yard	91.44	0.9144	0.0009144	36	3	1	.000568182
Mile	160934.4	1609.344	1.609344	63360	5280	1760	1

SURFACES AND AREAS

UNITS	SQUARE INCHES	SQUARE FEET	SQUARE YARDS	ACRES	SQUARE MILES	SQUARE CENTIMETERS	SQUARE METERS
Square Inch	1	0.0069444	0.0007716	-	-	6.4516	.00064516
Square Foot	144	1	0.111111	-	-	929.0304	.09290304
Square Yard	1296	9	1	0.000206612	-	8361.2736	.83612736
Acre	6272640	43560	4840	1	0.0015625	40468564.2	4046.8564224
Square Mile	4014489600	27878400	3097600	640	1	25899881103.	2589988.11033
Sq Centimeter	0.1550003	0.0010764	0.00011960	-	-	1	.0001
Square Meter	1550.003	10.76391	1.1959899	0.000247105	-	10000	1

MASSES AND WEIGHTS

UNITS	POUNDS,TROY	POUNDS,AVOIR.	GRAMS	KILOGRAMS	SHORT TONS	LONG TONS	METRIC TONS
Pound, Troy	1	0.8228571	373.2417216	0.3732417216	0.0004114	0.0003673	.00037324
Pound,Avoir.	1.2152778	1	453.59237	0.45359237	0.0005	0.0004464	0.00045359237
Gram	0.0026792	0.0022046	1	0.001	-	-	0.000001
Kilogram	2.679229	2.204623	1000	1	0.00110231	0.0009842	0.001
Short Ton	2430.556	2000	907184.74	907.18474	1	0.8928571	0.90718474
Long Ton	2722.223	2240	1016046.9088	1016.0469088	1.12	1	1.0160469088
Metric Ton	2679.2298	2204.623	1000000	1000	1.102313	0.9842065	1

All light faced type numbers are exact.

ANGULAR MEASURE

UNITS	CIRCLE	DEGREES	GRADS	MILS	MINUTES	SECONDS	RADIANS
Circle	1	360	400	6400	21600	1296000	6.2831853
Degrees	.0027778	1	1.111111	17.777778	60	3600	0.01745329
Grads	.00250	0.9000000	1	16	54	3240	0.01570796
Mils	.000156	0.05625	0.06250	1	3.3750	202.50	0.00098175
Minutes	-	0.016667	0.0185185	0.2962963	1	60	0.000290888
Seconds	-	0.000278	0.00030864	0.0049383	0.01667	1	-
Radians	.159155	57.295788	63.66199	1018.58925	3437.7492	206265	1

VOLUME AND CAPACITY

UNITS	CUBIC INCHES	CUBIC FEET	CUBIC YARDS	LITERS	QUARTS, DRY	CUBIC METERS	
Cubic Inch	1	0.0005787	0.00002143	0.016387064	0.0148808	.000016387064	
Cubic Foot	1728	1	0.03703704	28.316846592	25.71405	.028316846592	
Cubic Yard	46656	27	1	764.554857984	694.27935	.764554857984	
Liter	61.02374	0.03531467	0.00130795	1	0.90808298	.001	
Quart, Dry	67.200625	0.03888925	0.0014403	1.101221	1	.001101221	
Cubic Meter	61023.74	35.31467	1.3079506	1000	908.08	1	

All light faced type numbers are exact.

i. Problems.

(1) Find:

(a) C° if F° = 59°
(b) F° if C° = 30°
(c) F° if C° = 94°
(d) C° if F° = -4°
(e) C° if F° = 32°
(f) C° if F° = 130°
(g) F° if C° = 72°
(h) You are checking your tape for the appropriate tape correction. Your tape is standardized at 68° F but you have a metric thermometer. What °C is equal to 68° F?

(2) Convert:

(a) 1200 mm to cm
(b) 150 cm to m
(c) 2535 km to m
(d) 150 dm to km
(e) 1200 hm to km
(f) 12.5 m to yds
(g) 135 in to cm
(h) 125 cm to ft
(i) 12 3/8 ft to m
(j) 127.5 m to ft
(k) 100 in^3 to liters
(l) 125 liters to cubic inches
(m) 12 ft^3 to liters
(n) 1 in^2 to cm^2
(o) 137 yd^3 to m^3

ALGEBRA

1. ADDITION AND SUBTRACTION. (Ref: Sec VII, para 45-51, CRM Text)

a. Add the following:

(1) $a + b$ and $a - b$
(2) $5x^2 + 6x - 2$ and $3x^2 - 7x + 2$
(3) $ax^2 + bx - 4$; $3ax^2 - 2bx + 4$; $-4ax^2 - 2bx + 5$
(4) $x^4 - 3x^3 + 2x^2 - 4x + 7$; $3x^4 + 2x^3 + x^2 -5x -6$;
$4x^4 + 3x^3 -3x^2 + 9x -2$
(5) $3x^2 - xy +xz -3y^2 - z^2$; $-5x^2 -xy -xz + 5yz$;
$+y^2 + 3z^2 + 3yz$; $6x^2 + 4xz - 6y - 6z$; $5xz + 4yz$

b. Subtract:

(1) $2a - 3b - 3c$ from $8a - 4b - 2c$
(2) $-5a^2 c + 6a^2 b + b^3$ from $5a^2 c + 6a^2 b - 8a^3$
(3) $3x^4 + ax^3 - 4bx^3 + 6cx + d$ from $x^4 + 3ax^3 - 2bx^2 + 3cx - 4d$

c. Simplify:

(1) $a - b\,[a - (b - c) - c]$
(2) $a - [b + c - a - (a + b) - c] + [2a - (b + c)]$

2. MULTIPLICATION. (Ref: Sec X, para 54-57, CRM Text)

Multiply the following:

a. $x + 10$ by $x + 6$
b. $x + 3$ by $x - 3$
c. $a^2 - 7a + 2$ by $a^2 - 2a + 3$
d. $x^3 + 4x^2 + 5x - 24$ by $x^2 - 4x + 11$
e. $x - 3$ by $2x + 3$

3. DIVISION. (Ref: Sec XI, para 58-60, CRM Text)

Divide

a. $x^2 + 2xy$ by x
b. $- 30a^7 + 20a^9$ by $- 10a^6$
c. $a^2 + 7a + 12$ by $a + 4$
d. $a^3 - 8a - 3$ by $- a + 3$
e. $x^3 + 3x^2 y + 3 xy^2 + y^3 + z^3$ by $x + y + z$

4. EQUATION SOLVING.

a. Solve for x and verify the answer.

(1) $5x - 4 = 16$
(2) $5x = 3x + 6$
(3) $4x - 11 = 2x - 5$
(4) $6(3x - 1) - 8x = 140 + 2 (x - 1)$
(5) $(5x + 3) - 2 (x - 1) + (1 - x) = 4 (9 - x)$
(6) $7 - 21 (x + 3) = 13 - 15 (2x - 5)$
(7) $5 (x - 3) - 7 (6 - x) + 29 = 50 - 3 (8 - x)$

b. If a number is multiplied by 9, the product is 810. Find the number.

c. A tree 100 feet high was broken so that the part broken off was 9 times the length of the part left standing. Find the length of each part.

d. Three times a given number diminished by 20 is equal to the given number. Find the number.

e. A tank, capacity 1500 gallons, has three pipes. The first lets in 8 gallons a minute, the second 10 gallons, and the third 12 gallons a minute. In how many minutes will the tank be filled?

f. A man is now twice as old as his son; 20 years ago he was four times as old as his son. Find the age of each.

5. LAWS OF EXPONENTS.

a. We must remember the basic laws of exponents. These are:

(1) Law I: $a^m a^n = a^{m+n}$
(2) Law II: $(a^m)n = a^{mn}$
(3) Law III: $(ab)^n = a^n b^n$
(4) Law IV: $(a/b)^n = a^n/b^n$
(5) Law V: $a^m/a^n = a^{m-n}$
(6) Law VI: $\sqrt[n]{a^m} = a^{m/n}$

b. In other words:

(1) If we multiply: We add exponents.
(2) If we divide: We subtract exponents.
(3) If we raise to a power: We multiply the exponents by the power which we raise.
(4) If we extract a root: We divide the exponents by the index of the root.

This, in fact, is all we need to remember of the Law of Exponents. Please note: We neither "add" nor "subtract", by use of exponents.

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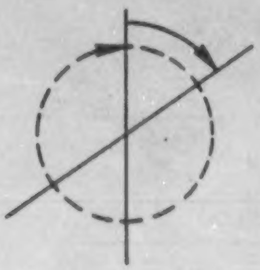
GEOMETRY

1. DEFINITION. (Ref: CRM, Section XIII, para 68)

Geometry is the basis of mathematics for the surveyor. Simply defined, it is the study of shape. Everything the surveyor does is related to geometry.

2. ANGLES. (Ref: CRM, Section XVI, para 81)

a. The intersection of two lines forms an angle. The meeting point is called the vertex. The measurement of the angle is determined by the rotation of one line from another.



A complete rotation is divided into 360 parts called degrees (shown by dotted line). Each degree is divided either by decimals or by 60 minutes per degree and 60 seconds per minute. In the metric system a complete rotation is divided into 400 grads.

b. In working with angle measurements there are two conversion factors that will be quite handy:

1° (degree) = 60 (minutes)

1' (minute) = 60 (seconds)

(1) The steps to be followed in converting are as follows:

For converting degrees and minutes to decimal degrees and vice-versa:

$$\frac{\text{No. of Minutes}}{60} = \text{decimal degrees}$$

(a) Convert $92^\circ\ 32'$ to decimal degrees

$$\frac{32\ \text{minutes}}{60} = .533^\circ \text{degrees}$$

ANS: 92.533°

(b) Convert 63.45° to minutes

$60 \times .45^\circ = 27$ minutes

ANS: $63^\circ\ 27'$

(2) The same proportion will hold true when converting seconds to decimal minutes and vice-versa:

$$\frac{\text{No. of seconds}}{60} = \text{decimal minutes}$$

3. SUPPLEMENTARY DEFINITIONS.

a. Angles.

(1) Straight Angle - angle equal to 180°.

(2) Reflex Angle - angle greater than 180° but less than 360°.

(3) Scalene Triangle - A triangle where no two sides are equal; therefore, no two angles are equal.

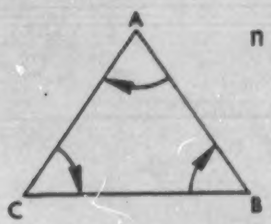
(4) Congruent Triangles - If two sides of a triangle are equal to two sides of another triangle and the included angles in both triangles are equal, then the triangles are congruent.

(5) Sum of the Interior Angles (for a polygon)

$$\Sigma \measuredangle i = (n - 2)\ 180^\circ$$

where n is the number of interior angles in the figure .

EX:



n = 3 interior angles:

ABC, BCA and CAB

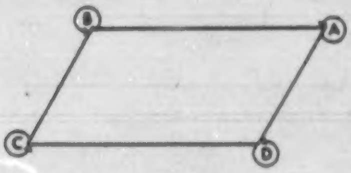
$$\Sigma \sphericalangle i = (n - 2)\ 180^\circ$$
$$\Sigma \sphericalangle i = (3 - 2)\ 180^\circ$$
$$\Sigma \sphericalangle i = (1)\ 180^\circ$$
$$\Sigma \sphericalangle i = 180^\circ \text{ for a triangle}$$

(6) Sum of the exterior angles (for a polygon)

$$\Sigma = (n + 2)\ 180^\circ$$

where n equals the number of exterior angles

EX:

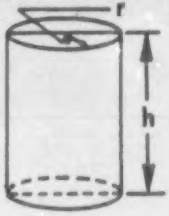


n = 4 exterior angles: ABC, BCD, CDA and DAB

$$\Sigma = (n + 2)\ 180^\circ$$
$$\Sigma = (4 + 2)\ 180^\circ$$
$$\Sigma = (6)\ 180^\circ$$
$$\Sigma = 1080^\circ \text{ for a quadrilateral}$$

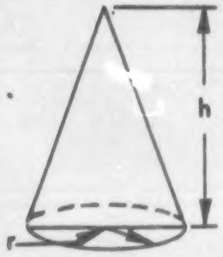
b. Solids (Three Dimensional Figures)

(1) Cylinder (of constant radius)



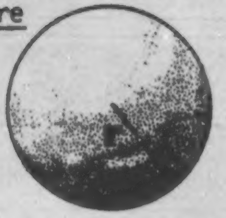
Vol = $\pi r^2 h$

(2) Cone



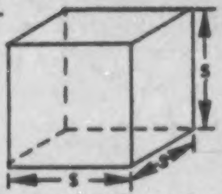
Vol = 1/3 $\pi r^2 h$

(3) Sphere



Vol = 4/3 πr^3

(4) Cube

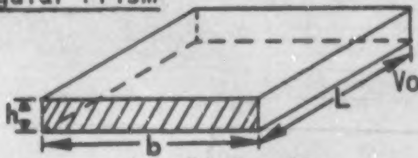


Vol = S^3

c. Prism (of constant cross-section)

Vol = (area of base) (length)

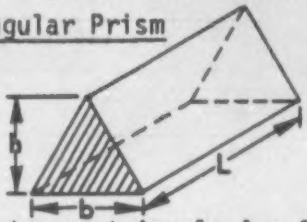
(1) Rectangular Prism



Vol = bh · L

Shaded area rectangle A = bh

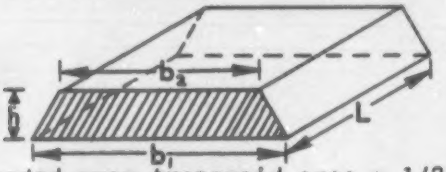
(2) Triangular Prism



Vol = 1/2 bh · L

Shaded area triangle A = 1/2bh

(3) Trapezoidal Prism



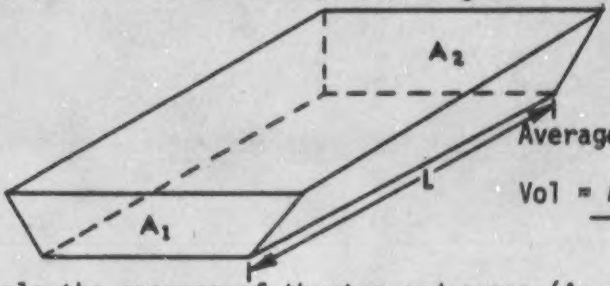
Vol = 1/2h (b_1 + b $_2$) · L

Shaded area trapezoid area = 1/2 h (b_1 + b_2)

d. Volume Formulas

(1) In surveying, problems often arise as to volumes of earth to be removed for a cut or added for a fill. In a problem such as this, the figure usually does not have a constant cross-sectional area; therefore, prism formulas will not apply.

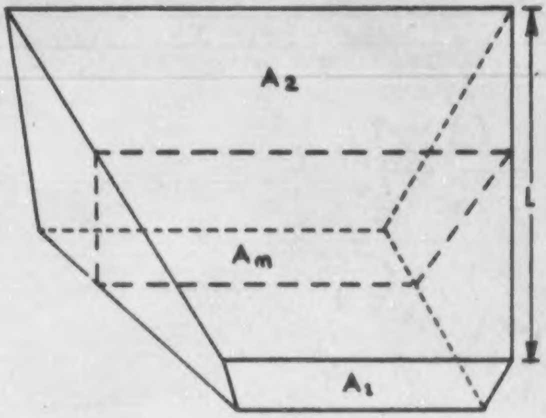
(2) For approximate volume of this type the surveyor will usually use one of two formulas, according to the accuracy needed:



Average End Area Formula

$$\text{Vol} = \frac{A_1 + A_2}{2} L$$

Volume equals the average of the two end areas ($A_1 + A_2$) times the distance between the two end areas.



Prismoidal Formula

(More accurate than Average End Area Formula)

$$\text{Vol} = \frac{A_1 + 4A_m + A_2}{6} L$$

Volume equals the average of the two end areas (A_1 and A_2) plus four times A_m where A_m is found by meaning the corresponding linear dimensions of the end sections A_1 & A_2.

4. PROBLEMS.

a. Convert the following:

(1) 25° 10' to decimal degrees
(2) 21° 13' 42" to decimal degrees
(3) 68° 04' 18" to decimal degrees
(4) 82° 34' 55" to decimal degrees

(5) 82.315° to degrees, minutes and seconds
(6) 98.887° to degrees, minutes and seconds
(7) 162.431° to degrees, minutes and seconds
(8) 145.56421° to degrees, minutes and seconds

b. Find the sum of the interior angles for the following polygons.

(1) Hexagon (6 sided)
(2) rhombus (4 sided)
(3) pentagon (5 sided)
(4) dodecagon (12 sided)

c. Find the sum of the exterior angles for the following polygons.

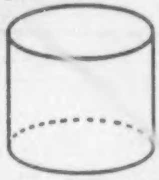
(1) triangle
(2) square
(3) octagon (8 sided)
(4) decagon (10 sided)
(5) heptagon (7 sided)

d. Find the Volumes of the following figures in cubic feet.

(1) sphere - $r = 3$ feet
(2) cone - $r = 9$ inches; $h = 1$ foot
(3) cylinder - $r = 80$ feet; $h = 21$ feet
(4) square - $s = 8$ feet

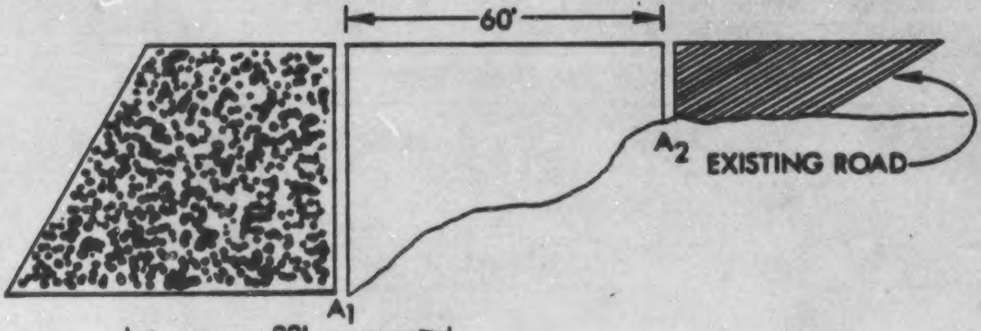
e. Solve the following problems.

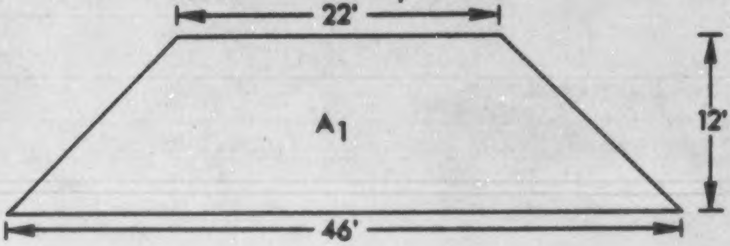
(1) cylinder: Vol = 40 cu ft; $h = 10$; $r = ?$
(2) Mr. Jones wants to paint the outside of a gasoline storage tank (see figure) that is 80 feet high and 200 feet in diameter. How much paint must he buy if 1 gallon will cover 90 square feet?

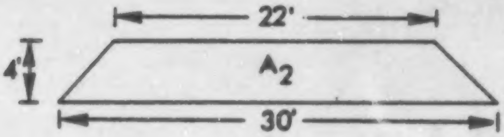


(3) In order to build a road, a fill must be constructed across a swamp. The cross section of the fill is a trapezoid. At one end it has an area of 32 square yards and the other 48 square yards. If the distance is 430 feet, what volume of earth will be needed? (yd^3).

(4) A road is to be built between an existing road and a bridge abutment. Figure the volume using the prismoidal formula.


60'
A1
A2
EXISTING ROAD





LOGARITHMS

(Ref: CRM, Sec. XVII Para 83, to Sec. XIX Para 94)

The treatment of logarithms, as per above cited references, is completely adequate, however, following is a slightly different approach which should prove helpful.

1. DEFINITION.

The logarithm of a given number is the power to which another number (called the base) must be raised to equal the given number.

EXAMPLE: Find the logarithm of 1000 to the base 10. From the definition, the logarithm of a number (1000) is the power (x) to which another number called the base (10) must be raised to equal the given number (1000). Thus, $10^x = 1000$. Since $10^3 = 1000$, then: $10^x = 10^3$ and, by inspection $x = 3$. Therefore, the logarithm of 1000 to the base 10 equals 3 or $\log_{10} 1000 = 3$. Since Common Logarithms use the number 10 as a base, and since they are so universally used, the number 10 (as in $\log_{10}$) is usually omitted. We now just write: $\log 1000 = 3$.

2. PARTS OF LOGARITHMS.

a. Logarithms are divided into two parts, the integer and the decimal, or as we call them: the CHARACTERISTIC and the MANTISSA.

b. The characteristic of any number greater than 1 is one less than the number of digits to the left of the decimal point. If there are no numbers to the left of the decimal point, the characteristic is negative. Thus, the characteristic for the number 3 is 1-1 or zero, since there is one number to the left of the decimal point. The characteristic for 30, with two numbers to the left of the decimal point, is 2-1 or 1. Similarly, the characteristic for 300 is 2, and the characteristic for 3000 is 3.

c. The characteristic of the log of a decimal is negative and is based upon the position of the first rational number to the right of the decimal point. In the number .327, for example, the first significant number is the first decimal place and the characteristic is -1. Similarly, the characteristic for .003 is -3, and the characteristic for .0003 is -4.

d. The decimal part of the logarithm is called the mantissa. The mantissa is what is recorded in logarithm tables and is always the same for a given sequence of digits, regardless of where the decimal point appears among them. Thus, the mantissa is the same for 1570, 157.0, 15.7, 1.57. The characteristic tells us where the decimal point belongs. The logarithms of the numbers are, respectively, 3.195 900, 2.195 900, 1.195 900 and 0.195 900.

REMEMBER: The mantissa is always positive even when the characteristic is negative. As we said before: the only thing the characteristic tells us is where to place the decimal point (or where it was). We should not say, for example, that the logarithm of .157 is -1.195 900. What we mean to say is -1. followed by a +.195 900. To overcome this we write the negative (minus) sign above the characteristic and make it long enough to cover the entire negative portion of the logarithm. Therefore, we would write the log of .157 as $\bar{1}$.195 900.

e. This use of negative characteristics used in conjunction with positive mantissas creates a problem in the addition and subtraction of logarithms. What we do to eliminate this complication is this: we add 10.0 to the characteristic--and then subtract 10 from the whole logarithm. It will work like this: we found the log of .157 to be $\bar{1}$.195 900. We now add 10 to the characteristic and subtract 10 from the whole log.

$$\begin{array}{r} 10.000\ 000 - 10 \\ \underline{\bar{1}.195\ 900} \\ 9.195\ 900 - 10 \end{array}$$

We can readily see that 9-10 = -1. Also, the log of .0157 = $\bar{2}$.195 900 which we write as 8.195 900 - 10.

f. Finding a Logarithm. Any standard table of logarithms is used in basically the same manner. We shall discuss here the tables found in TM 5-233. These are "6 place tables". Thus, by inspection, we can see that this permits direct readings of 4 place numbers. To go beyond 4 places we have to interpolate for the additional places required. Interpolation is discussed later in this section.

REMEMBER: Logarithmic Tables consist of MANTISSAS only. The characteristic must be determined in each instance by following the rules given in paragraph 2b and 2c of this section.

EXAMPLE 1: Find the logarithm of 345.6

1st - The characteristic is 3-1, or 2.

2nd - Find the mantissa of 3456. Note that we will look up the given succession of digits, regardless of the location of the decimal point.

3rd - Open log tables to the place where under the N column you find 345 and then follow horizontally along this line until you read the column headed -6.

4th- Record the logarithm as follows: characteristic = 2. ----mantissa = .538574. Thus, the logarithm of 345.6 is 2.538574.

EXAMPLE 2: Find the logarithm of 0.02345

1st - Determine the characteristic of 0.02345 It is -2, or 8. -- -10.

2nd - Look down the N column for 234. Move finger horizontally across the page to the 5 column.

3rd - Log 0.02345 = 8.370143-10

EXAMPLE 3: Find the logarithm of 34567

1st - The characteristic is 5-1. or 4.

2nd - We look for the mantissa of 34567 and find that this table lets us look up only 3456 and we get 53 8574; the "7" we have to interpolate. Interpolation will be covered in para 3.

In a similar way we find the log for 0.023456, finding out that the direct reading will stop at 2345, leaving the "6" to be interpolated.

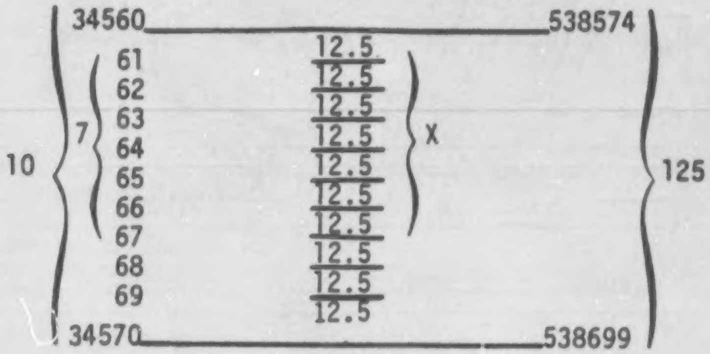
3. LOGARITHMIC INTERPOLATION.

a. As we discovered previously, TM 5-233 permits direct extraction of logarithms for numbers which do not exceed four significant digits.

If the logarithm has more than 4 places, we must find the proportional part of the difference between the two logarithms and add this difference to the lower one. This operation is called interpolation.

b. In TM 5-233 lists of proportional parts have been supplied and should be used. If, however, no such tables are furnished, think of interpolation along these lines: supposing we want to find the logarithm of 34567 and our table allows us to read only to 3456. We must now interpolate for the 7 i.e. we must find the value in logarithms which corresponds with this 7. Let us now consider the distance from 3456 to 3457 divided into 10 equal parts and find the value in logarithms for these 10 parts, which in this case, is 125. So each 1/10 is equal to 12.5 and 7 x 12.5 = 87.5 = 88. We now add this 88 to the log of 3456 resulting in the log for 34567.

c. In order to facilitate interpolation, each page of logarithms has listed on it, or the next page, a list of proportional parts. We then operate as follows:



$\frac{7}{10} :: \frac{X}{125}$ X = 87.5

Log 34567 = 538574
$+ \quad 88$
538662

(1) Look up log to as many places as the table permits.
(2) Determine the difference between the two successive logs.
(3) Enter the Proportional Parts Table under the column headed by your difference.
(4) Read the proportional part to be added to your logarithm along the line of the number you are working with.
(5) Read and record the proportional part (rounded properly).
(6) Add this proportional part to the logarithm (lower one).
(7) The sum of the two is the logarithm you seek.

d. Should an additional number be needed, let's say we are looking for the logarithm of 345678, we know, that we can originally only go to 3456 — we still have the remaining 78 to interpolate.

e. In b. above, we divided the difference between the two successive logarithms into 10 equal parts — now let us divide the difference into 100 parts (divide each 1/10 into 10 parts).

f. Again, let us look up our sequence of numbers as far as we can go directly, that is: we look up the logarithm of 3456 and find 538574. The log for 3457 is 538699, giving us a difference of 125 for interpolation. The log we seek lies 78/100 beyond the log of 3456, that means we must add 78/100 of the difference to this log:

$$78/100 \text{ of } 125 = \frac{78 \times 125}{100} = 1.25 \times 78 = 97.50 \text{ or } 98.$$

This interpolation can also be affected by using the tables of proportional parts as follows:

(1) Enter proportional parts table for 125.

(2) Write down the proportional parts for 7 = 87.5.

(3) Then write the proportional part for 8 = 100.0.

(4) Add these two, considering the 8 as 8/10, as follows:

$$\begin{array}{r} 87.5 \\ \underline{10.0} \\ \overline{97.5} = 98 \end{array}$$

(5) Next add 98 to the log of 3456 and we get

$$\begin{array}{rr} & 538\ 574 \\ & \underline{98} \\ \log 345678 = & 538\ 672 \end{array}$$

4. FINDING THE ANTILOGARITHM.

a. Up to now we have discussed the steps to be followed when finding the logarithm of a given number. Now we, naturally, arrive at the point where we are given the logarithm and are looking for the number represented by this log. We call this process: Finding the Antilogarithm. The steps to follow are the reverse process of what we did when we looked up the logarithm.

b. Let us discuss first the placement of the decimal point in our number. If you recall from the first part of this lesson we stated that the characteristic of a log is one less than the number of digits to the left of the decimal point. In finding the antilog, we locate the decimal point one more place than the characteristic indicates, on the number we find. If the characteristic is NEGATIVE we place our decimal point, and then count to the right the number of spaces in our negative characteristic, filling in zeros until we come to our first significant number. For example the antilog of 7.768 638-10 is found as follows: First, we look up the number represented by a mantissa of 768 638 and find it to be 5870. Next we determine the location of our decimal point (7 - 10 = -3). So we put down our decimal point and then count three places to the right where the number begins. (.005870.)

c. Interpolation, when working on antilogs, is performed in the reverse from interpolation for logarithms. Let us say we are looking for the antilog of 2.390 061.

(1) First, we look in Table B-1 TM 5-233 for 390061 and find 390 051 and 390 228. We note that the first log is too small, the second is too large. This tells us that our number is greater than 2455 but less than 2456.

(2) We put down the number which goes with the log of the smaller: 2455. Next find the difference in logs between the log of 2455 and 2456, this = 177. Next we find how many log units there are between the log of 2455 (390 051) and our log (390061) this is 390 061 - 390 051 = 10.

(3) We now go to the proportional parts table and look under 177 for 10. The closest we can find to this number is 17.7 and above this we find the number 1. This number we append to the number which corresponds to the lower log (2455) and get 24551.

(4) Last we place our decimal point. Our characteristic is 2, so we point off 2 + 1 or 3 places from left to right and we get an antilog of 2.390061 = 245.51.

5. ARITHMETIC COMPUTATIONS BY LOGARITHMS.

a. In Algebra we learned that when multiplying factors (with the same base) we ADD their exponents. When dividing we SUBTRACT, when raising to a certain power, we MULTIPLY; and when extracting a root, we DIVIDE by the index of the root.

REMEMBER: MULTIPLY - ADD
DIVIDE - SUBTRACT
RAISE - MULTIPLY
EXTRACT ROOT - DIVIDE

The above are the ONLY operations which can be performed by use of logs. Since the logarithms we use are all to the base 10 we can add, subtract, multiply, or divide logarithms to effect the desired operation.

b. At this point we should discuss the use of COLOGARITHMS (COLOG). The same result can be obtained by adding a colog as by subtracting a logarithm.

c. The principle of adding the cologs is based on the following fact: $\frac{a \times b \times c}{d \times e}$ is the same as a x b x c x 1/d x 1/e.

d. We can see that in the latter operation we have only multiplication, no divisions. If we used the first form, we would add the logs of a, b, and c. We would then subtract the sum of the logs of d and e from the sum of the logs of a, b, and c to get our result. Now to the 1/d and 1/e. We know the log of "1" is 0. So we must subtract the log of "X" from 0 to get the colog. Supposing "X" was equal to 126. The log of 126 = 2.100 371. We cannot subtract 2.100 371 from "0". But if we subtitute 10 - 10 (which is equal to "0") then we have

$$\begin{array}{rl} 10.000\ 000 & - 10 \\ \underline{-2.100\ 371} & \\ 7.899\ 629 & - 10 \end{array}$$

e. If we look at the above subtraction we see that as soon as we subtract the first integer, the remaining "0's" all become "9's". This always being true, let us write down a log as a colog: we merely subtract (from left to right) each number from "9" except the last significant one which we subtract from "10". Now, our original problem of $\frac{a \times b \times c}{d \times e}$ will set up as: a x b x c 1/d x 1/e.

f. It is highly recommended that computations be set up according to the following sample:

(1) Find the value of $\frac{a \times b \times c}{d \times e}$

log a =
log b =
log c =
colog d =
colog e =
log answer ________
answer ________

88

g. Problems.

(1) Find the following:

(a) log 246.13
(b) log 3765.47
(c) log 0.24^3
(d) log 0.002468
(e) log 3.4567
(f) log $\sqrt{127648}$
(g) log 24680.1
(h) log 39.784^2
(i) log $\sqrt[3]{142.678}$
(j) log 34.1234
(k) anitlog 3.678 124
(l) antilog $\bar{1}.246\ 398$
(m) antilog 0.194 687
(n) antilog 8.261 918 − 10
(o) antilog 4.000 000
(p) antilog 5.794 318
(q) antilog 2.876 543
(r) antilog 7.234 127 − 10
(s) antilog 4.578 394
(t) antilog $\bar{4}.578\ 394$
(u) colog 127.42
(v) colog 287.39
(w) colog 7249.00
(x) colog 2748.62

(2) Find the values of the following, using logs:

(a) 2764.3 x 1.724
(b) 39.876 x 0.2481
(c) 0.0139 x 27.618 x 2.4689
(d) 127 x 246 x 6.39
(e) 246 x 0.54321 x 27
(f) $\frac{129.34}{68.42}$
(g) $\frac{246.39}{127.34}$
(h) $\frac{795.36}{468.33}$
(i) $\frac{127.394}{0.039}$
(j) $\frac{127.394}{0.0036}$

(k) $\dfrac{394.6 \times 13.942 \times 127.69 \times 15}{150.69 \times 68.456 \times 15.32}$

(l) $\dfrac{271 \times 354 \times 12^3}{132 \times 175}$

(m) $\sqrt{\dfrac{165 \times 227 \times 32}{15^2 \times 12}}$

(n) $\sqrt[3]{\dfrac{2274.3 \times 156.23}{32^3}}$

(o) $\sqrt{\dfrac{123^2 \times 127^2 \times 65^3}{75^3 \times 144^2}}$

TRIGONOMETRY

1. NATURAL FUNCTIONS OF ANGLES.

a. Before discussing trigonometric solutions, we must be familiar with the use of "NATURAL FUNCTIONS" of various angles.

(1) Natural Functions are mathematical values of the various ratios each of which represent a particular angle.

(2) A knowledge of the various ratios and the use of Natural Functions allow us to solve many survey problems to include heights, distances, directions and positions.

b. TM-5-233 contains tables of natural functions (sin, cos, tan and cot) from 0° to 90° and this section is geared to the use of these tables.

c. We have previously learned the definitions for these functions and should you not be familiar with them it is suggested that you refresh yourselves at this time. (See page 41.)

d. Now let us take our tables of Natural Functions, Table B-3, TM-5 233, page 215:

(1) We find, on top of the page, the number of degrees and eight columns, labeled Sin., d." (for difference); Tan., d.", Cot., d.", Cos. and d.".

(2) On the left hand side of the tables we have a column for each minute which is read DOWN the page.

(3) The angle entries increase to 45° across the top of the pages. After 45°, we read the angles on the BOTTOM of the page and use the Sin, Tan, Cot and Cos columns on the bottom of the page. Also, the minute column on the RIGHT side of the page is read UP.

(4) To get the natural sine of 7° 24' 34" we proceed as follows:

(a) At the top of the page look for 7° (page 222).
(b) At the left hand minute column go DOWN to 24' where we find 0.128 796.

ANNEX 1 to SECTION XX -XXIV

(c) Going to the difference column we find 4.80 between 24' and 25'. This 4.80 is the difference per second.

(d) Since we have 34" we multiply 34 by 4.80, getting 163.2 = or 163.

(e) Add 163 to the natural sine of 7° 24' (.128 796 + 163 = .128 959).

(5) Upon further examination of our natural function tables we find that the functions of sin and tan INCREASE as the angle increases. The functions of cos and cot DECREASE as the angle increases. So if we were looking for the natural cos of 7° 24' 34" we would proceed as follows:

(a) At the top of the page look for 7° .

(b) Go down the left hand minute column to 24' where we find .991671 (under the Cos column).

(c) In the difference column (between 24' and 25') we find .62 (difference per second).

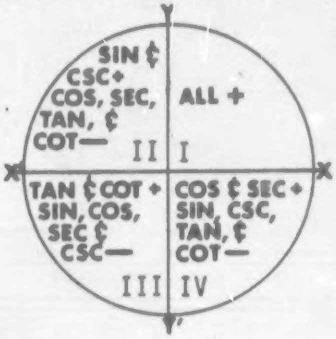
(d) We also see that the natural cos of 7° 25' is less than that for 7° 24'.

(e) Our natural function is then less than .991671 by .62 x 34 = 21.08 or 21.

(f) The natural cos of 7° 24' 34" is then .991671 - 21 or .991650.

Just remember this rule of thumb: In direct functions, i.e. sin and tan we ADD the proportional part and in the CO-FUNCTIONS we SUBTRACT.

(6) At this point we must discuss, very briefly, the sign of the various functions in the four quadrants which we originate on the horizon and revolve counterclockwise. Refer to the following sketch.



e. If an angle is greater than 90° you may determine its function by one of the two methods below:

(1) Subtract the given angle from 180° and use the same function.

(2) Subtract 90° from the given angle and use the co-function. (Use the sketch on preceding page to determine the sign of the function)

f. Problems. Find the value of the function with the proper sign:

(1) sin 37° 21'
(2) cos 37° 21'
(3) tan 37° 21'
(4) cot 37° 21'
(5) sin 44° 30' 26"
(6) cos 22° 28' 54"
(7) tan 17° 27' 38"
(8) cot 27° 18' 51"
(9) sin 49° 27' 38"
(10) cos 54° 29' 54"
(11) tan 75° 25' 25"
(12) cot 87° 57' 32"
(13) sin 63° 54' 23"
(14) cos 61° 59' 59"
(15) tan 51° 50' 27"
(16) cot 72° 27' 38"
(17) sin 112° 27' 54"
(18) cos 121° 34' 32"
(19) tan 145° 21' 21"
(20) cot 160° 27' 27"

2. LOGARITHMS OF FUNCTIONS OF ANGLES. (Ref: Para 98-100, CRM Text)

a. Logarithms of Trigonometric functions are, in fact, nothing more than the logarithms of the natural functions of the various angles. For instance, let us look up the sine of 30° (natural function) and we find 0.500000. If we now look up the logarithm of 0.500000 Table B-1, we find 9.698970-10. Next, let us go to our logarithmic tables of functions of angles, Table B-2, and look up the log sine 30° and there we find 9.698970-10.

b. The practical use of the tables is the same as for natural functions, i.e. angles from 0° to 45° are entered with the angle as well as the function columns listed on top of the page and the minutes and seconds entries are read DOWN along the left hand edge of the tables. From 45° to 90° we enter along the bottom of the page and UP on the right hand side.

c. TM 5-233 Table B-2 shows entries for every 1 minute of angle with the difference for 1 second entered in the D.1"(difference per second) columns.

d. Let us suppose that we are looking for the logarithm of the sine of 25° 45' 28". We would proceed as follows:

(1) Along the top of the page (195) we look for 25° and down the left side for 45' and we find 9.637935 (log sine 25° 45'). (-10 is omitted)

(2) Looking in the D.1" column we see the difference per second between 45' and 46' is 4.37 units. We now multiply 28 seconds x 4.37 units of difference per second which = 122.36 units = 122.

(3) Our desired logarithm is 122 units above the entry for 25° 45'. We add the value for 25° 45' to the value for 28".

$$\begin{array}{lcr} 25^{\circ}\ 45' & = & 9.637935-10 \\ +\quad 28'' & = & +\quad 122 \\ \hline & & 9.638057-10 \end{array}$$

(4) The cosine of the same angle would be found in the same manner, i.e., log cos 25° 45' = 9.954579-10 and for 25° 45' 28" the log would be: 28" x 1.02 (D.1") = 28.56 = 29;

$$\begin{array}{r} 9.954579-10 \\ -\quad 029 \\ \hline 9.954550-10 \end{array}$$

e. In finding antilogarithms of logs of functions we proceed as follows:

(1) Let us look for the antilogarithm for log sin = 9.698433-10.

(2) In the log section of our tables, under the sine column we look for 9.698433 (or the log numerically immediately below.)

(3) We find 9.698313 which goes with an angle of 29° 57'.

(4) Note the column D.1" value for 57' to 58'; it is 3.65 units per second.

(5) The difference between our log (9.698433) and the log for 29° 57' is (9.698433 - 9.968313) = 120.

(6) Divide the units of difference between the logs by the units per second: 120 ÷ 3.65 = 32.88 = 33 seconds.

(7) Hence, the antilog of log sine 9.698433-10 is 29° 57' + 33" = 29° 57' 33".

f. If we are looking for the antilog of cotangent 9.632 909-10, we proceed as follows:

(1) Under the cotangent column we look for 9.632901.

(2) The number immediately above this logarithm, numerically, is 9.633099 (remember - cot decreases as the angle increases) which corresponds to an angle of 66° 45'.

(3) Note the column D.1" value for 45' to 46'. It is 5.82.

(4) The difference between our log and the log of 66° 45' is:

$$\begin{array}{r} .633099 \\ -\underline{.632901} \\ 198 \end{array}$$

(5) Divide the units of difference between the logs by the units per second: 198 ÷ 5.82 = 34"

(6) Hence, the antilog for cot 9.632901-10 is 66° 45' + 34" = 66° 45' 34".

g. Problems. Find the logarithms of the following:

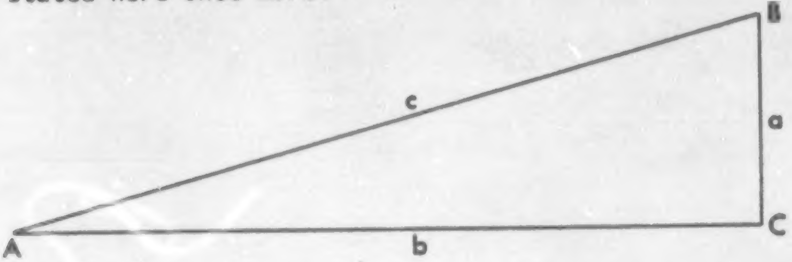
(1) sin 27° 27' 27"
(2) cos 38° 15' 19"
(3) tan 42° 42' 21"
(4) cot 15° 14' 13"
(5) sin 67° 22' 38"
(6) cos 75° 58' 48"
(7) tan 84° 17' 20"
(8) cot 53° 27' 45"
(9) sin 127° 54' 24"
(10) cos 154° 30' 32"
(11) tan 115° 37' 28"
(12) cot 131° 54' 12"
(13) sin 27° 54' 14"
(14) cos 111° 11' 11"
(15) tan 117° 27' 12"
(16) cot 47° 42' 41"
(17) sin 54° 24' 51"
(18) cos 171° 00' 21"
(19) tan 123° 51' 00"
(20) cot 110° 50' 37"

3. THE RIGHT TRIANGLE (Ref: CRM, Sec XXII para 101 to Sec XXIII para 106)

a. Read the above reference which discusses the arrangement of work, triangle formulas and furnishes all possible formulas for solutions. This extract also sets up each formula for a solution using logarithms.

b. Follow the given solutions carefully and you should not experience any difficulties in the solutions of right triangles.

c. Solution of Right Triangles. In high school geometry we learned the ratios (∡ 's to sides) which apply to right triangles. For a review they are stated here once more:



Using the basic relationships, we have:

$$\sin = \frac{\text{opposite side}}{\text{hypotenuse}}$$

$$\cos = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

$$\tan = \frac{\text{opposite side}}{\text{adjacent side}}$$

$$\cot = \frac{\text{adjacent side}}{\text{opposite side}}$$

Also $a^2 + b^2 = c^2$
(Pythagorean theorem)

We can now state, for the triangle above, that:

$\sin A = \frac{a}{c}$ $\qquad$ $\sin B = \frac{b}{c}$

$\cos A = \frac{b}{c}$ $\qquad$ $\cos B = \frac{a}{c}$

$\tan A = \frac{a}{b}$ $\qquad$ AND $\qquad$ $\tan B = \frac{b}{a}$

$\cot A = \frac{b}{a}$ $\qquad$ $\cot B = \frac{a}{b}$

From the above we can, depending on what parts of the triangle are given, select a ratio which contains two of the given parts and solve for the third.

Our formulas reduce as follows:

$$c^2 = a^2 + b^2 \therefore c = \sqrt{a^2 + b^2}$$

$$b^2 = c^2 - a^2 \therefore b = \sqrt{c^2 - a^2}$$

$$a^2 = c^2 - b^2 \therefore a = \sqrt{c^2 - b^2}$$

If $\sin A = \frac{a}{c}$ then $a = c \sin A$ and $c = \frac{a}{\sin A}$

$\cos A = \frac{b}{c}$ " $b = c \cos A$ " $c = \frac{b}{\cos A}$

$\tan A = \frac{a}{b}$ " $a = b \tan A$ " $b = \frac{a}{\tan A}$

$\cot A = \frac{b}{a}$ " $b = a \cot A$ " $a = \frac{b}{\cot A}$

And if

$\sin B = \frac{b}{c}$ then $b = c \sin B$ and $c = \frac{b}{\sin B}$

$\cos B = \frac{a}{c}$ " $a = c \cos B$ " $c = \frac{a}{\cos B}$

$\tan B = \frac{b}{a}$ " $b = a \tan B$ " $a = \frac{b}{\tan B}$

$\cot B = \frac{a}{b}$ " $a = b \cot B$ " $b = \frac{a}{\cot B}$

Solutions, using logs, should generally follow this format:

$a = c \sin A$

log c =

log sin A = ____________

log a =

a =

$c = \frac{a}{\sin A}$

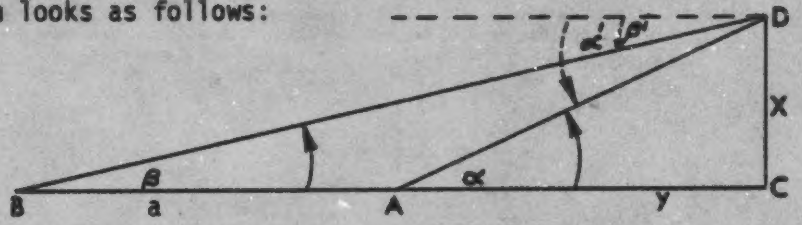
log a =

colog sin A = ____________

log c =

c =

d. Occasionally we are required to solve a set of triangles, the sketch of which looks as follows:



(1) We may be given the angles of elevation (α & β) or the angles of depression (α' and β') and we know, of course, that the angles of depression are equal to the angles of elevation, and vice versa.

(2) We are usually furnished the two angles and side "a", or "x", and are looking for "x" or "a" respectively. Here we have two right triangles.

(a) In rt Δ BDC: $\cot\beta = \frac{a+y}{x} \therefore a + y = x \cot\beta$ (1)

(b) In rt Δ ADC: $\cot\alpha = \frac{y}{x} \therefore y = x\cot\alpha$ (2)

By substitution in (1) & (2) above,

$$a = x\cot\beta - x\cot\alpha$$

$$a = x(\cot\beta - \cot\alpha)$$

$$\text{and } x = \frac{a}{\cot\beta - \cot\alpha}$$

From these two formulas:

$$a = x(\cot\beta - \cot\alpha)$$

and $x = \frac{a}{\cot\beta - \cot\alpha}$, we can solve for a or x, depending on the given parts.

NOTE: Remember that Logarithms do not permit us to perform subtractions $\therefore$ use Natural Functions.

e. Problems. (lengths of sides to two decimal places)

(1) In right triangle ABC, A = 34° 28', c = 18.75; find B, a, and b

(2) In right triangle ABC, A = 62° 10', a = 78; find B, b, and c

(3) In right triangle ABC, A = 50° 02', b = 88; find B, a, and c

(4) In right triangle ABC, c = 58.40, a = 47.55; find A, B, and b

(5) In right triangle ABC, a = 40, b = 27; find A, B, and c

(6) Find the legs of a right triangle if the hypotenuse is 6, and one of the unknown angles is twice the other.

(7) From the top of a hill the angles of depression of two successive milestones on a straight level road leading to the hill, are observed to be 5° and 15°. Find the height of the hill. (In feet)

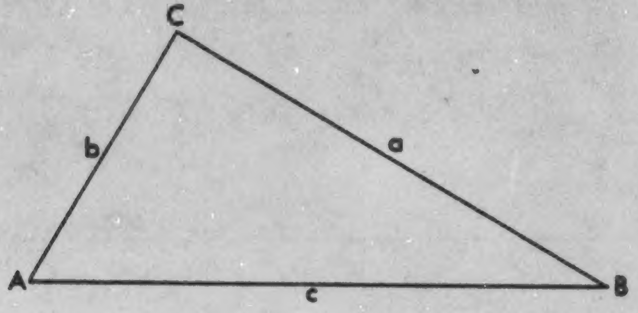
(8) The angle of elevation to the top (C) of an inaccessible hill from point A is 12°. At a point B, 219 feet from A and on a line AB perpendicular to AC, the angle ABC is 61° 45'. Find the height of the hill. (Short base method)

4. THE OBLIQUE TRIANGLE (Ref: CRM, Section XXIV, para 107-110)

a. As in the previous section on the Right Triangle, read the above reference which discusses the relationship between the sides of a triangle and the sines of their opposite angles. Other trigonometric laws which are conveniently used under certain conditions are also explained.

b. Become familiar with the application for the various laws. Follow the given solutions carefully and you should not experience any difficulty in the solutions of oblique triangles.

c. Solution of Triangles using the Law of Sines. When faced with the requirement to solve a given triangle, the first law you think of is the Law of Sines. Draw yourself a sketch and if, by inspection, you then determine that, of the parts given, one of them is a side opposite a given angle, the Law of Sines may be employed. (Remember you need to know the side opposite a given angle.)



Your formula for the Law of Sines is as follows:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Two of the three ratios are used to solve a particular problem making sure that the pair selected contains three known values and one unknown.

So we have:

$$\frac{a}{\sin A} = \frac{b}{\sin B} \quad \text{from which} \quad a = \frac{b \sin A}{\sin B}$$

$$b = \frac{a \sin B}{\sin A}$$

$$\frac{a}{\sin A} = \frac{c}{\sin C} \quad \text{from which} \quad a = \frac{c \sin A}{\sin C}$$

$$c = \frac{a \sin C}{\sin A}$$

$$\frac{c}{\sin C} = \frac{b}{\sin B} \quad \text{from which} \quad b = \frac{c \sin B}{\sin C}$$

$$c = \frac{b \sin C}{\sin B}$$

The format for setting up your solutions using logarithms is as follows:

log b =	log a =
log sin A =	log sin B =
colog sin B = __________	colog sin A = __________
log a =	log b =
a =	b =

or

log c =	log a =
log sin A =	log sin C =
colog sin C = __________	colog sin A = __________
log a =	log c =
a =	c =

or

log c =

log sin B =

colog sin C = ________

log b =

b =

log b =

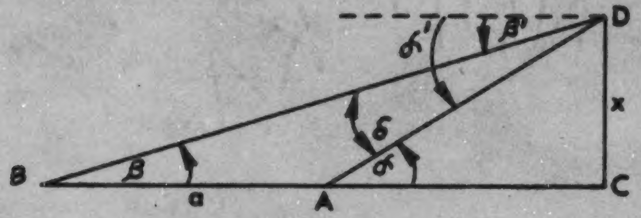
log sin C =

colog sin B = ________

log c =

c =

d. Problems using Oblique Triangles.



To solve for x, when α, β, and a are given:

(1) By natural functions:

In triangle ABD solve for AD using Law of Sines

(a) $\measuredangle BDA = \measuredangle\alpha' - \measuredangle\beta' = \measuredangle\delta$

(b) Then: $\frac{a}{\sin\delta} = \frac{AD}{\sin\beta}$ or $AD = \frac{a \sin\beta}{\sin\delta}$

(c) In Δ ADC: $\sin\alpha = \frac{X}{AD}$ or $x = AD \sin\alpha$

(d) Consequently: $X = \frac{a \sin\beta \sin\alpha}{\sin\delta}$

(2) A logarithmic solution from (d) above, would look like this:

log a =

log sin β =

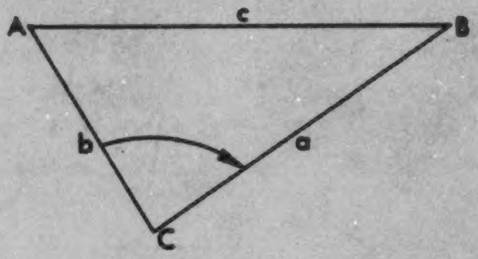
log sin α =

colog sin δ = ________

log x =

x =

e. Solution of Triangles using the Law of Tangents. The Law of Tangents is used to solve triangles when two sides and the angle between them are given. It is most conveniently used when solving this type of problem by the use of logarithms. If natural functions are to be used, it is suggested that the Law of Cosines (see page 49) be adopted.
Given: a, b, & C



The basic formula in the Law of Tangents is:

$$\tan 1/2\,(A - B) = \frac{(a-b)\tan 1/2\,(A + B)}{a + b}$$

The formula, as stated above, will solve for ∡ A & ∡ B, providing side a is greater than side b. If side b is greater than side a, the formula changes to:

$$\tan 1/2\,(B - A) = \frac{(b-a)\tan 1/2\,(B + A)}{b + a}$$

If combinations of any other two sides are given, the formula changes accordingly. A mechanical method for determining which form the formula will have is as follows:

(1) Determine which of the two given sides is the larger and record this side first on the format listed below.

(2) Record the smaller side next.

(3) Arrange format to follow the sequence established by 1 and 2 above.

(4) Enter logs and solve.

Given a, b, & $\angle$ C

$a > b$

a = log (a - b) =

b = log tan 1/2 (A + B) =

a + b colog (a + b) = __________

a - b log tan 1/2 (A - B) =

A + B = 180° - C = 1/2 (A - B) =

1/2 (A + B) =

1/2 (A - B) = __________

(Add) A =

(Subtr) B =

With angles A and B now known, we can now compute for side c, using the Law of Sines. Since both A and B are known, we should compute for side c in two ways, giving us a check of our computations.

Our formulas are:

$\frac{c}{\sin C} = \frac{a}{\sin A}$ hence: $c = \frac{a \sin C}{\sin A}$

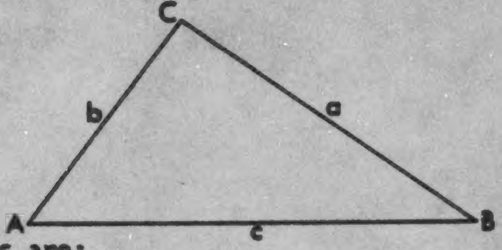
Also:

$\frac{c}{\sin C} = \frac{b}{\sin B}$ hence: $c = \frac{b \sin C}{\sin B}$

Which we set up as follows:

log a =	log b =
log sin C =	log sin C =
colog sin A = __________	colog sin B = __________
log c =	log c =
c =	c =

f. Solution of Triangles, using Tangent of 1/2 Angle Formulas. When three sides of a triangle are given, we may use the formulas for the tangents of 1/2 the angles to solve the triangle.



The three formulas are:

$$\tan 1/2\ A = \sqrt{\frac{(s-b)\ (s-c)}{s\ (s-a)}}$$

$$\tan 1/2\ B = \sqrt{\frac{(s-a)\ (s-c)}{s\ (s-b)}}$$

$$\tan 1/2\ C = \sqrt{\frac{(s-a)\ (s-b)}{s\ (s-c)}}$$

Where s = 1/2 the sum of the given sides $(s = \frac{a + b + c}{2})$

The following format is suggested for setting up the solutions:

a =	log (s-b) =	log (s-a)=	log (s-a) =
b =	log (s-c) =	log (s-c)=	log (s-b) =
c =	colog s =	colog s =	colog s =
2s =	colog (s-a) =	colog (s-b) =	colog (s-c)=
s =	$2\overline{)\qquad}$	$2\overline{)\qquad}$	$2\overline{)\qquad}$
s-a =	log tan 1/2 A =	log tan 1/2 B	log tan 1/2 C =
s-b =	1/2 A =	1/2 B =	1/2 C =
s-c	A =	B =	C =

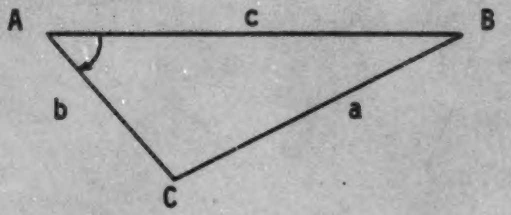
The above formulas may also be solved by using natural functions.

If you follow the above format, writing it down before entering the values, you will not easily overlook the fact that the $\sqrt{\qquad}$ requires division by 2, and also that you have solved for 1/2 the angle and must multiply this by 2 for the value of the required angle.

g. Solution of Triangles using the Law of Cosines. The Law of Cosines is used to solve triangles when three sides or two sides and the included angle are given.

(1) When two sides and the included angle are given the following procedures are used:

Given: c, b, & A



The basic formula in the Law of Cosines is:

$$a^2 = b^2 + c^2 - 2bc \text{ Cosine } A$$

The formula, as stated above, will solve for a^2, with 'a' being the square root thereof. Particular attention should be given to the last element of the formula. As noted on page 36, the sign of the Cosine of an angle in the second quadrant ($90^{\circ} - 180^{\circ}$) is minus. Therefore, the result of the multiplication of -2bc Cosine A would algebraically become a positive value and be added to the first two terms.

The original formula can also be rearranged to obtain b, and c if you are given a, b & C or a, c & B. So we have:

$$b^2 = a^2 + c^2 - 2ac \text{ Cosine } B \quad \text{and}$$

$$c^2 = a^2 + b^2 - 2ab \text{ Cosine } C$$

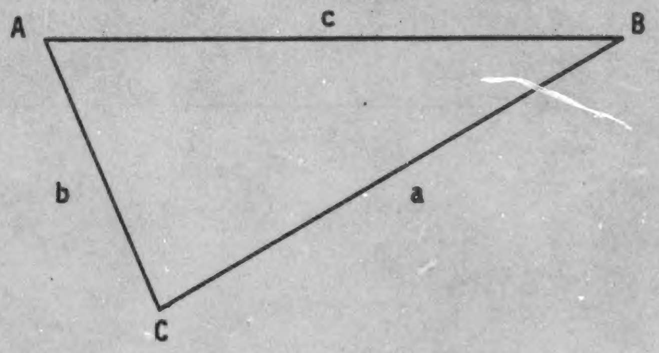
With one angle, and all three sides known, we can now solve for the other two angles using the Law of Sines:

$$\frac{a}{\sin A} = \frac{b}{\sin B} \qquad \text{hence;} \quad \text{Sin } B = \frac{b \text{ Sin } A}{a}$$

Also:

$$\frac{a}{\sin A} = \frac{c}{\sin C} \qquad \text{hence;} \quad \text{Sin } C = \frac{C \text{ Sin } A}{a}$$

(2) When three sides of a triangle are given, we may also use the formulas for the Law of Cosines to solve the triangle. However, since we must solve for the unknown angles, we must transpose the basic formula to isolate the Cosine on the left side of the equation.



The three formulas become:

$$\text{Cos } A = \frac{b^2 + c^2 - a^2}{2\,bc}$$

$$\text{Cos } B = \frac{a^2 + c^2 - b^2}{2\,ac}$$

$$\text{Cos } C = \frac{a^2 + b^2 - c^2}{2\,ab}$$

With one angle known and the three sides which were given, you can now solve the remainder of the triangle using the Law of Sines. An alternate solution would be to repeat the use of the Law of Cosines for the other two angles. To solve for only two angles and conclude the third is not good practice. All three angles should be computed independently and added to ensure a 180° summation.

h. Problems.

(1) Given: $a = 804$, $A = 99^\circ 55'$ $B = 45^\circ 01'$ Find C, b, c

(2) Given: $b = 999$, $A = 37^\circ 58'$ $C = 65^\circ 02'$ Find B, a, c

(3) Given: $a = 4.4$, $b = 5.21$, $A = 57^\circ 37' 17''$ Find B,C,c

(4) Given: $a = 77.99$, $b = 83.39$, $C = 72^\circ 15'$ Find A, B, c

(5) Given: $a = 47.99$, $b = 33.14$, $C = 175^\circ 19' 10''$
Find A, B, c

(6) Given: $a = 51$, $b = 65$, $c = 20$ Find the angles

(7) Given: $a = 43$, $b = 50$, $c = 57$ Find the angles

(8) Determine the distance of an enemy gun at position A from your position at B. Given: line BC is 322.55 yds, angle ABC is $60^\circ 34'$ and angle BCA is $56^\circ 10'$.

(9) In order to find the distance between two objects, A and B, separated by a swamp, a station C was chosen, and the distances CA = 3825 yds, CB = 3475.6 yds were measured. Angle ACB was measured and found to be $62^\circ 31'$. Find the distance between A and B.

(10) Of three towns A, B, and C, A is 200 miles from B and 184 miles from C, B is 150 miles due north from C. How far is A north of C?

ANSWERS TO PROBLEMS

Page 1 - a.	(1)	8340	(2)	2188	(3)	5954
	(4)	215812	(5)	212491		
b.	(1)	23797	(2)	1809	(3)	1889
	(4)	3889	(5)	4778		
c.	(1)	71t	(2)	82957		
Page 2 - c.	(1)	2 1/4	(2)	2 1/16	(3)	2 1/32
	(4)	3 13/64	(5)	2 59/64	(6)	4 14/25
	(7)	3 17/27	(8)	2 15/16	(9)	2 9/68
	(10)	2 27/44	(11)	11 1/4	(12)	41 3/32
	(13)	1 1/8	(14)	12 1/8	(15)	3 139/210
	(16)	21/32	(17)	5/192	(18)	7/36
	(19)	288 15/64	(20)	1344 51/112	(21)	3/4
	(22)	1/6	(23)	2 1/6	(24)	11 2/3
	(25)	110	(26)	3/8	(27)	10/27
	(28)	1/8	(29)	33 3/4	(30)	24 5/14

Page 3 - b.	(1),				
	(a)	.375	.625	.875	
	(b)	.3	.03	.003	
	(c)	.25	.5	.75	
	(d)	.2	.4	.6	.8
	(e)	.42857	.22222	.90909	.9375
	(f)	1.92308	2.875	13.48	100.75
	(g)	25.9375	37.375	12.34375	
	(h)	15.46667	28.1792	19.51542	
	(i)	28	212.2	115.33333	
	(j)	127.66667	184.625		
Page 4 - b.	(2),				
	(a)	1 5/8	3 3/4	16 7/8	
	(b)	1/2	1/2	2/3	
	(c)	3 1/8	1 339/500	2 139/250	
	(d)	127 1/3	12 211/500	1 89/100	
	(e)	11 27/40	14 321/1000	11 123/1000	
	(3),				
	(a)	525.3766			
	(b)	338.9964			
	(c)	390.860			
	(d)	4500.19667			
	(e)	36910.4581			

Answers Continued......

Page 4 - b.	(4).				
	(a)	1567.3841			
	(b)	963.775			
	(c)	1394.6662			
	(d)	27.303			
	(e)	161.845			
	(5).				
	(a)	1.347			
	(b)	.86956			
Page 5 - c.	(1)				
	(a)	5184	361	784	196
	(b)	144	81	289	256
	(c)	225	15625	5625	2500
	(d)	2362369			
	(e)	54756			
	(2)				
	(a)	27	216	6859	1728
	(b)	8	64	343	512
	(c)	50653			
	(d)	180362125			
	(e)	2048383			
	(3)				
	(a)	191			
	(b)	306			
	(c)	731			
	(d)	11.20			
	(e)	931.00			
Page 6 - 5 a.	(1)				
	(a)	3.5			
	(b)	3.0			
	(c)	2.0			
	(d)	1.059			
	(e)	.875			
	(2)	A = \$30.00	B = \$70.00		
	(3)	33/51			
	(4)	7/2	18/7	$\frac{\text{50 feet}}{\text{10 feet}}$	$\frac{2\ 4/5}{22\ 1/2}$
	(5)	1.25:100	or 1.25%		

Answers Continued.......

Page 6 - 5 a. (6) 58.33

(7) 300 feet

(8) 113 1/7 feet

(9) 10 Days

Page 10 - (1)
(a) 20%
(b) 25%
(c) 33 1/3%
(d) 75%
(e) 25%
(f) 76.5%
(g) 60.8%
(h) 224%

(2)
(a) 29.167%
(b) 12.5%
(c) 62.5%
(d) 87.5%

(3)
(a) 1440 cu yds
(b) 170 men
(c) 368 gals
(d) 27 men
(e) 342 cu yds
(f) 5%

Page 15 - i. (1)
(a) 15°
(b) 86°
(c) 201.2°
(d) -20°
(e) 0°
(f) 54.4°
(g) 161.6°
(h) 20°

(2)
(a) 120 cm
(b) 1.5 m
(c) 2535000 m

Answers Continued......

Page 15 - 1. (2)
(d) .015 Km
(e) 120 Km
(f) 13.67 yds
(g) 342.9 cm
(h) 4.101 ft
(i) 3.772 m
(j) 418.31 ft
(k) 1.6387 L
(1) 7627.97
(m) 339.80
(n) 6.452 cm^2
(o) 104.7440 m^3

Page 16 - 1 a.(1) $2a$
(2) $8x^2 - x$
(3) $-3bx + 5$
(4) $8x^4 + 2x^3 - 1$
(5) $4x^2 - 2xy + 9xz - 2y^2 + 2z^2 + 12yz - 6y - 6z$

b.(1) $6a-b+c$
(2) $10a^2 c-8a^3 -b^3$
(3) $-2x^4 + 2ax^3 + 4bx^3 - 2bx^2 - 3cx - 5d$

c.(1) $a - ab + b^2$
(2) $5a - b - c$

2 (a) $x^2 + 16x + 60$
(b) $x^2 - 9$
(c) $a^4 + 9a^3 + 19a^2 - 25a + 6$
(d) $x^5 + 151x - 264$
(e) $2x^2 - 3x - 9$

3 (a) $x + 2y$
(b) $3a - 2a^3$
(c) $a + 3$
(d) $-a^2 - 3a - 1$
(e) $x^2 + 2xy - xz + y^2 - yz + z^2$

Page 17 - 4 a.(1) $x = 4$
(2) $x = 3$
(3) $x = 3$
(4) $x = 18$
(5) $x = 5$
(6) $x = 16$
(7) $x = 6$

Answers Continued........

Page 17 - 4 b. 90

c. 10 feet and 90 feet

d. 10

e. 50 min

f. Present age of father is 60 yrs.
Present age of son is 30 yrs.

Page 23 - 4 a. (1) 25.1667°
(2) 21.2283°
(3) 68.0717°
(4) 82.5819°
(5) 82° 18' 54"
(6) 98° 53' 13.2"
(7) 162° 25' 51.6"
(8) 145° 33' 51.2"

b. (1) 720°
(2) 360°
(3) 540°
(4) 1800°

c. (1) 900°
(2) 1080°
(3) 1800°
(4) 2160°
(5) 1620°

d. (1) 113.1 cu. ft.
(2) 0.58905 cu. ft.
(3) 422230.05 cu. ft.
(4) 512 cu. ft.

e. (1) 1.13 ft.
(2) 558.5 gals.
(3) 5733.33 cu. yds.
(4) 545.2 cu. yds.

Answers Continued ......

Page 33 - g. (1)

(a) 2.391165
(b) 3.575819
(c) 8.140634-10
(d) 7.392345-10
(e) 0.538662
(f) 2.553007
(g) 4.392347
(h) 3,199417
(i) 0.718119
(j) 1.533052
(k) 4765.7
(l) .17636
(m) 1.5656
(n) .018278
(o) 10,000.00
(p) 622760
(q) 752.56
(r) .0017145
(s) 37,879.
(t) .00037879
(u) 7.894762-10
(v) 7.541528-10
(w) 6.139722-10
(x) 6.560885-10

(2)

(a) 4765.6
(b) 9.8932
(c) .94778
(d) 199640
(e) 3608.0
(f) 1.8904
(g) 1.9349
(h) 1.6983
(i) 3266.5
(j) 35,387
(k) 66.677
(l) 7176.3
(m) 21.069
(n) 2.2134
(o) 87.524

Answers Continued.......

Page 37 - f.	(1)	0.606682
	(2)	0.794944
	(3)	0.763176
	(4)	1.310314
	(5)	0.700999
	(6)	0.924002
	(7)	0.314542
	(8)	1.936289
	(9)	0.759959
	(10)	0.580727
	(11)	3.84556
	(12)	0.035639
	(13)	0.898077
	(14)	0.469476
	(15)	1.272639
	(16)	0.316056
	(17)	0.924113
	(18)	-0.523622
	(19)	-0.690992
	(20)	-2.817270
Page 39 - g.	(1)	9.663786-10
	(2)	9.895013-10
	(3)	9.965184-10
	(4)	0.564814
	(5)	9.965229-10
	(6)	9.384283-10
	(7)	0.999961
	(8)	9.869803-10
	(9)	9.897084-10
	(10)	9.955520-10
	(11)	0.319081
	(12)	9.952964-10
	(13)	9.670236-10
	(14)	9.557992-10
	(15)	0.284387
	(16)	9.958835-10
	(17)	9.910221-10
	(18)	9.994627-10
	(19)	0.173468
	(20)	9.580623-10
Page 42 - e.	(1)	a = 10.61; b = 15.46; B = 55° 32'
	(2)	b = 41.18; c = 88.20; B = 27° 50'
	(3)	B = 39° 58'; a = 105.00; c = 137.00
	(4)	A = 54° 30' 34"; B = 35° 29' 26"; b = 33.91

Answers Continued........

Page 42 - e. (5) $A = 55^\circ\ 58'\ 50''$; $B = 34^\circ\ 01'\ 10''$; $c = 48.26$
(6) $a = 3$; $b = 5.1962$
(7) $x = 685.89$ feet
(8) Ht of hill = 84.74 feet

Page 51 - h. (1) $C = 35^\circ\ 04'$; $b = 577.30$; $c = 468.93$
(2) $B = 77^\circ$; $a = 630.75$; $c = 929.47$
(3) $B = 89^\circ\ 52'\ 48''$; $C = 32^\circ\ 29'\ 55''$ $c = 2.7992$
(4) $A = 51^\circ\ 15'$; $B = 56^\circ\ 30'$; $c = 95.24$
(5) $A = 2^\circ\ 46'\ 08''$; $B = 1^\circ\ 54'\ 42''$; $c = 81.06$
(6) $A = 38^\circ\ 52'\ 48''$; $B = 126^\circ\ 52'\ 12''$; $C = 14^\circ\ 15'\ 00''$
(7) $A = 46^\circ\ 49'\ 35''$; $B = 57^\circ\ 59'\ 44''$; $C = 75^\circ\ 10'\ 41''$
(8) 300 yds
(9) 3800 yds
(10) 54.52 miles

BASIC ARITHMETIC

(RATIO AND PROPORTION)

Programmed Lesson

TABLE OF CONTENTS

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BASIC ARITHMETIC

(Ratio and Proportion)

OBJECTIVES OF THIS LESSON

Upon completion of this lesson, you should be able to:

1. Define ratio and proportion.
2. Express ratio and proportion in both written and verbal forms.
3. Explain the different terms used in ratio and proportion.
4. Learn and apply the rules of ratio and proportion.
5. Recognize the direct and inverse types of proportion.
6. Form a proportional equation, referred to as "setting up the problem."
7. Solve various types of problems involving ratio and proportion.

INSTRUCTIONS TO STUDENTS

The material in this lesson is arranged in small steps, called frames. Each frame contains information which you must know. Each frame requires that you respond by completing an incomplete statement.

The correct response is stated on the reverse side of the page. Once you complete a frame, check your answer and continue with the next frame.

Begin with frame #1 at level A (upper third of each frame page) and continue through all frames at this level. Once you have completed all frames at level A begin level B (middle third of each frame page) and work all frames at this level. After completing levels A and B you may begin level C (lower third of each frame page) working all of the problems.

Proceed through the lesson at your own speed. You will have two hours to complete the lesson, so pace yourself accordingly. If you need help with a problem do not hesitate to call on an instructor.

FRAME #1 **LEVEL A**

A ratio is a relation or comparison of one quantity to another quantity of the same kind. Therefore, in mathematics we use ratio to r__________ or c___________ two similar quantities.

NOTE: Do not work below this line until all frames in LEVEL A are complete.

FRAME #14 **LEVEL B**

Bob and Dick agreed to divide profits of $45.00 in ratio of 2 to 3, Dick securing the larger share. How much should each receive?

a. Bob________________ b. Dick________________

NOTE: Do not work below this line until all frames in LEVEL B are complete.

FRAME #27 **LEVEL C**

Refer to Frame #25. In order to simplify setting up this problem, we mentally phrase the verbal expression of this direct proportion. We say: "6 workmen is to X workmen as 1800 articles is to 2700 articles." We write this as

$\frac{6}{X} = \frac{1800}{2700}$ or 6:X = 1800:2700. Complete the solution:

$1800X = 16,200;$

$X =$ ______________.

NOTE: The same kinds are compared: "workmen are to workmen as articles are to articles."

FRAME #1 (Response)

relate, compare

FRAME #14 (Response)

a. Bob $18.00 b. Dick $27.00

FRAME #27 (Response)

X = 9

FRAME #2 **LEVEL A**

A ratio may be written with two figures placed vertically and separated by a horizontal line across the middle in a form of fraction. Example: A ratio of 2 to 3 is written $\frac{2}{3}$; hence, a ratio of 3 to 2 is written ____________.

FRAME #15 **LEVEL B**

Two fishermen agreed to divide a fish 3 feet 9 inches long in the ratio of 4 to 5. How long is each section?

a. Shorter ______________ b. Longer ____________

FRAME #28 **LEVEL C**

Refer to Frame #26. In phrasing the verbal expression of this inverse proportion, we say: "6 workmen is to 15 workmen as 10 days is to X days." This is normally written $\frac{6}{15} = \frac{10}{X}$ or 6:15 = 10:X but since an increase in one quantity causes a decrease in another quantity this is an inverse proportion and one side of the equation must be inverted. Hence, it is written $\frac{6}{15} = \frac{X}{10}$ or 6:15 = X:10. Complete the solution:

15X = 60; X = ____________.

FRAME #2 (Response)

$\frac{3}{2}$

FRAME #15 (Response)

a. 20 inches b. 25 inches

FRAME #28 (Response)

4

FRAME #3 **LEVEL A**

A ratio may be written also with two figures placed horizontally and separated by a colon. Example: A ratio of 2 to 3 may be written 2:3; hence a ratio of 3 to 2 is written ______.

FRAME #16 **LEVEL B**

Mr. Smith left directions to divide his estate among three children in the ratios 2:3:4. If the estate amounted to $54,000, how much should each part be?

______ ______ ______

This completes the lesson frame on ratios. Now, proceed to proportion.

FRAME #29 **LEVEL C**

Now let's set up different types of problems concerned in mapping. Type 1. The scale of a map is 1:25,000. What is the map distance if the distance on the ground is 1250 feet? Express in inches. In phrasing the verbal expression, we say: 1 is to 25,000 as map distance (unknown) is to ground distance (1250 ft.). We write as

$$\frac{1}{25000} = \frac{X}{1250 \times 12''}$$

Complete the solution: ______

114

FRAME #3 (Response)

3:2

FRAME #16 (Response)

$12,000 $18,000 $24,000

FRAME #29 (Response)

25,000 X = 15,000 X - .6 inches

125

FRAME #4 **LEVEL A**

A ratio of $\frac{1}{4}$ (1:4) is verbally expressed as one to four.

Then a ratio of $\frac{4}{1}$ (4:1) is verbally expressed as ______________.

PROPORTION

FRAME #17 **LEVEL B**

If the ratio of two numbers equals the ratio of two other numbers, the four numbers form a proportion. Example: $\frac{2}{3} = \frac{4}{6}$, $\frac{1}{2} = \frac{2}{4}$.
What number should represent the letter (X) to form a proportion of the following equation?

a. $\frac{3}{5} = \frac{X}{10}$ b. $\frac{4}{5} = \frac{8}{X}$

FRAME #30 **LEVEL C**

Type 2. The scale of a map is 1:35,000. What is the ground distance if the distance on the map is 1.8 inches? Express in feet. We say, 1 is to 35,000 as map distance (1.8") is to ground distance (unknown). We write $\frac{1}{35000} = \frac{1.8}{X}$.
Complete the solution: $\frac{35,000 \times 1.8}{12} =$ ________________.

FRAME #4 (Response)

4 to 1

FRAME #17 (Response)

a. 6 b. 10

FRAME #30 (Response)

5,250 feet

FRAME #5 **LEVEL A**

The grouping of two quantities in ratio is called the quotient. The two quantities of a ratio are called the terms of a ratio, such as "first term" and "second term". In a ratio of $\frac{3}{4}$ or 3:4, the first term is 3, and 4 is the second term. In the ratio of $\frac{4}{3}$ or 4:3, 4 is the ______ ________ and 3 is the ______ ________.

FRAME #18 **LEVEL B**

In a proportion $\frac{2}{3} = \frac{4}{6}$ or 2:3 = 4:6 is called the first term of this proportion, 3 the second term, 4 the third term and 6 the fourth term. Then, in a proportion $\frac{2}{7} = \frac{4}{14}$ or 2:7 = 4:14, the second and third terms are ________ and __________; first and fourth terms are ________ and ________.

FRAME #31 **LEVEL C**

Type 3. The distance between two points on a map is 3.6 inches. The distance between the same two points on the ground is 3520 yards. What is the scale of the map? We say: scale = $\frac{1}{X}$ = 1:X. 1 is to X as 3.6 inches is to 3520 yards.

We write $\frac{1}{X} = \frac{3.6}{3520 \times 36}$. Complete the solution

X = __________. Scale = __________.

FRAME #5 (Response)

first term, second term

FRAME #18 (Response)

7 and 4, 2 and 14

FRAME #31 (Response)

35,200; 1:35,200

FRAME #6 **LEVEL A**

In a ratio, the first term and the second term are individually called the antecedent and the consequent. Hence, when referring to a ratio of $\frac{4}{5}$ (4:5), 4 is the ____________ and 5 is the __________.

FRAME #19 **LEVEL B**

In a proportion $\frac{2}{3} = \frac{4}{6}$ or 2:3 = 4:6, the first and fourth terms (2 and 6) are also called the extremes, and the second and third terms (3 and 4) are called the means of this proportion. Then, in a proportion $\frac{5}{6} = \frac{10}{12}$ or 5:6 = 10:12 (6 and 10) are the ________ and (5 and 12) are the ___________.

FRAME #32 **LEVEL C**

Type 4. The distance between two points on a captured enemy map is 2.54 inches. The same distance on a map in your possession, with a scale of 1:50,000 is 6.35 inches. What is the scale of the enemy map? We phrase this: 1:X (enemy map) is to 1:50,000 (your map) as 2.54" is to 6.35". We write $\frac{X}{50000} = \frac{6.35}{2.54}$. (Note that the second part of the equation is inverted because the smaller the number the larger the denominator of scale.) Complete the solution: 2.54X = 317500.

X = ____________________. Scale = __________________.

FRAME #6 (Response)

antecedent, consequent

FRAME #19 (Response)

means, extremes

FRAME #32 (Response)

125,000, 1:125,000

FRAME #7 **LEVEL A**

RULE NO. 1. Both terms of a ratio may be multiplied or divided by a same number without changing the value of the ratio. Example

$\frac{2}{4} \times \frac{2}{2} = \frac{4}{8}$ $\frac{2}{4} \div \frac{2}{2} = \frac{1}{2}$ $\frac{2}{4} = \frac{4}{8} = \frac{1}{2}$

Complete the following:

a. $\frac{4}{6} \times \frac{2}{2} =$ b. $\frac{4}{6} \div \frac{2}{2} =$

FRAME #20 **LEVEL B**

IN A PROPORTION THE PRODUCT OF THE EXTREMES IS EQUAL TO THE PRODUCT OF THE MEANS. Example: In proportion $\frac{3}{5} = \frac{6}{10}$ or 3:5 = 6:10, product of extremes (3 and 10) equals 30 and product of means (5 and 6) equals 30. Which one of the following is NOT a proportion?

a. 2:5 = 4:8 b. $\frac{3}{5} = \frac{9}{15}$ c. $\frac{2}{3} = \frac{6}{9}$

FRAME #33 **LEVEL C**

If 12 pieces of furniture cost $72, what will 27 pieces cost at the same rate?

FRAME #7 (Response)

a. $\frac{8}{12}$ b. $\frac{2}{3}$

FRAME #20 (Response)

a. 2:5 - 4:8

FRAME #33 (Response)

$162

$$\frac{12}{27} = \frac{72}{X}$$

$$12X = 1944$$

$$X = 162$$

FRAME #8

LEVEL A

RULE NO. 2. Since ratios may be written in a form of fraction, rules pertaining to fractions may be used, such as reducing to lowest terms. Example: $\frac{6}{9}$ may be reduced to $\frac{2}{3}$. Write the following ratios in fractional form in their lowest terms:

a. 4:16 b. $\frac{3}{18}$ c. 9:24

FRAME #21

LEVEL B

Proportions, like ratios, may be written in different forms. A proportion $\frac{2}{3} = \frac{4}{6}$ may be written 2:3 = 4:6. Write the following in different forms:

a. $\frac{3}{4} = \frac{6}{8}$ (   ) b. 2:5 = 4:10 (   )

FRAME #34

LEVEL C

If 15 carpenters can construct a building in 28 days, in how many days can 21 carpenters do the same job?

FRAME #8 (Response)

a. $\frac{1}{4}$ b. $\frac{1}{6}$ c. $\frac{3}{8}$

FRAME #21 (Response)

a. 3:4 = 6:8 b. $\frac{2}{5} = \frac{4}{10}$

FRAME #34 (Response)

20 days

$$\frac{15}{21} = \frac{X}{28}$$

$$21X = 420$$

$$X = 20$$

FRAME #9 **LEVEL A**

RULE NO. 3. To find the value of a ratio, the first term (antecedent) is divided by the second term (consequent). Example: In a ratio $\frac{5}{8}$ or 5:8, 5 is divided by 8, to obtain the decimal value of .625. Show the decimal value of following ratios:

a. $\frac{1}{4}$ b. $\frac{3}{8}$ c. 4:7

FRAME #22 **LEVEL B**

A proportion $\frac{2}{4} = \frac{4}{8}$ or 2:4 = 4:8 is verbally expressed 2 is to 4 as 4 is to 8. Then, a proportion $\frac{3}{4} = \frac{6}{8}$ is verbally expressed:

________________________.

FRAME #35 **LEVEL C**

Driving from one town to the next, you get a speedometer reading of 6.5 miles. The same route on a map measures 11.44 inches. What is the scale of the map?

NOTE: 1 mile = 63,360 inches.

FRAME #9 (Response)

a. .25 b. .375 c. .571

FRAME #22 (Response)

3 is to 4 as 6 is to 8

FRAME #35 (Response)

1:36,000

$$\frac{1}{X} = \frac{11.44}{6.5 \times 63,360}$$

$$11.44X = 411840$$

$$X = 36,000$$

FRAME #10 **LEVEL A**

RULE NO. 4. In finding the ratio of two numbers, both numbers must be first expressed in the same unit of measure. Example: To find the ratio of 3 feet to 5 inches, the feet should first be converted to inches.

$$\frac{3 \times 12''}{5''} = \frac{35''}{5''} = \frac{7\frac{1}{5}}{1} \text{ or } \frac{7.2}{1} \text{ or } 7\tfrac{1}{5}:1 \text{ or } (7.2:1)$$

Find the ratio of the following:

a. 2 ft. to 2 yd. b. 2 in. to 3 yd. c. 5 mi. to 3 ft.

FRAME #23 **LEVEL B**

There are two types of proportion, direct and inverse. Direct proportion is when an increase in one quantity causes a proportional increase in another quantity, or when a decrease in one quantity causes a proportional ____________ in another quantity.

FRAME #36 **LEVEL C**

You have a map of 1:45,000 scale which you want to use on a fishing trip. The route you want to take measures 21.12 inches on the map. What is the ground distance, in miles?

FRAME #10 (Response)

a. 1:3 b. 1:54 c. 8800:1

FRAME #23 (Response)

decrease

FRAME #36 (Response)

15 miles

$$\frac{1}{45,000} = \frac{21.12}{X}$$

$$X = \frac{950400}{63360} = 15$$

FRAME #11 **LEVEL A**

Let's put our knowledge of ratio to work in solving a practical problem. In our school last year, there were 576 students. 96 were in the Cartographic Drafting course.

a. What is the ratio of Cartographic Drafting students to the whole school? ____________

b. What is the ratio of other (non-cartographic) students to Cartographic Drafting students? ____________

FRAME #24 **LEVEL B**

Inverse proportion: When an increase in one quantity causes a proportional decrease in another quantity, or a decrease in one quantity causes a proportional ____________ in another quantity.

FRAME #37 **LEVEL C**

Your map has a scale of 1:50,000. What is the distance on the map if the distance on the ground is 3750 feet?

Express answer in inches.

FRAME #11 (Response)

a. 1:6   b. 5:1

FRAME #24 (Response)

increase

FRAME #37 (Response)

.9 inches

$$\frac{1}{50,000} = \frac{X}{3750 \times 12}$$

$$50,000X = 45000$$

$$X = .9$$

FRAME #12 **LEVEL A**

Let's try another problem. In a class of 24 students, 3 students failed to pass the course.

a. What is the ratio of students who passed the course to the whole class? ____________________

b. What is the ratio of students who failed the course to students who passed the course? ______________

FRAME #25 **LEVEL B**

Example of direct proportion: "Six workmen make 1800 articles in one day. How many workmen would be needed to make 2700 such articles at the same rate?" This is a direct proportion because an increase in articles will require (a, an) ________________ in workmen.

FRAME #38 **LEVEL C**

The distance between two points on a map is 12.5 inches. The same distance on a map in your possession, with a scale of 1:100,000, is 8.6 inches. What is the scale of the first map?

132

FRAME #12 (Response)

a. 7:8 b. 1:7

FRAME #25 (Response)

increase

FRAME #38 (Response)

1:68,800

$$\frac{X}{100,000} = \frac{8.6}{12.5}$$

$$12.5X = 860,000$$

$$X = 68,800$$

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FRAME #13 **LEVEL A**

Let's try and solve more difficult problems. The sum of two numbers having a ratio of 1 to 3 is 32. What are the numbers? Solution: Let X represent the smaller number and 3X the larger number. X + 3X = 32. 4X = 32, X = 8; then 3X = 24. Check: Does 8 + 24 = 32? Yes. Solve this problem: Sum of two numbers having a ratio of 4 to 7 is 99. What are the numbers? a. Smaller no.________ b. Larger no. ______________

FRAME #26 **LEVEL B**

Example of inverse proportion: "Six workmen completed a job in ten days. How many days will it take fifteen workmen to do the same job?" This is an inverse proportion because an increase in workmen will ______________ the number of days.

FRAME #39 **LEVEL C**

The distance between two points on a 1:12,500 scale map is 14.1 inches. What is the distance between the same two points on a 1:23,500 scale map? Express answer in inches.

FRAME #13 (Response)

a. 36 b. 63

Return to Page 3 for **FRAME #14, LEVEL B**

FRAME #26 (Response)

decrease

Return to Page 3 for **FRAME #27, LEVEL C**

FRAME #39 (Response)

7.5 inches

$$\frac{12500}{23500} = \frac{X}{14.1}$$

$$23500X = 176250$$

$$X = 7.5$$

This completes all the lesson frames on ratio and proportion. Now, begin the SELF TEST on page 29.

SELF TEST

1. A ratio may be written with two figures placed ____________ and separated by a ________ __________ across the middle; they may also be written with two figures placed ____________ and separated by a ____________. (2, 3)

2. A ratio of 3/4 is verbally expressed as _______ ____ ______.(4)

3. In a ratio the first term is called the ____________ and the second term the ____________. (6)

4. The sum of two numbers having a ratio of 1 to 3 is 32. If X equals the smaller number, then _____ will equal the larger one. (13)

5. When the ratio of two numbers equals the ratio of two other numbers, the four numbers are called a ________________. (17)

6. In a proportion the product of the ______________ is equal to the product of the ______________. (20)

7. In a direct proportion an increase in one quantity causes a proportional ____________ in the other. (23)

8. In an inverse proportion a decrease in one quantity causes a proportional _____________ in the other. (24)

9. If five workmen can do a job in ten days, how many days will it take 20 men to do the job. (26)

10. Your map has a scale of 1:50,000. What is the distance on the map if the same distance on the ground is 5280 feet? ______(37)

ALGEBRA REVIEW

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Lesson Frames ---------- 5-28
Self-Test ---------- 29

INSTRUCTIONS TO STUDENTS

This type of programmed lesson is actually a workbook wherein the overall lesson information is broken down into small steps, called "**Frames**". Some frames require an action, labeled (Action); in these frames you do the action as directed. When you have completed the (R) statement or your action, turn page to next frame and continue lesson. The first line above each frame contains the correct response for the preceding frame. This serves as a check on your already written response — **NOT FOR COPYING.** These booklets are your property; they are not graded. This lesson is not a test (other than testing yourself) and you can proceed through it at your own speed. Frames 1 through 11, and 23 will be on odd numbered pages. Frames 12 through 22 will be on even numbered pages.

OBJECTIVES OF THIS LESSON

Upon completion of this lesson you will demonstrate the ability to solve and understand some of the most commonly basic algebraic formulas

Specifically the following:

a. Algebraic addition

b. Algebraic subtraction

c. Algebraic multiplication

d. Algebraic division

e. Formula transposition and transformation

FINAL INSTRUCTIONS

Remember that you continue through each frame in numercial order. You will probably get along all right on your own, but in case, you need help, just raise your hand, as the instructor is there to assist you.

FRAME #1

Algebra is that part of mathematics which employs letters in reasoning about numbers, either to find their general properties or to find the value of an unknown from its relation to known numbers.

R: In algebra, ____________ are used in reasoning about numbers.

TURN TO PAGE 6 FOR FRAME #2

(Monomial) (Binomial) (Polynomial)

FRAME #12

The absolute value of a number is its value without regard to the sign before it.

Example: The numbers +7 and −7 have the same absolute value, 7.

R: The absolute value of −3 and +3 is ________

FRAME #13 IS ON PAGE 7

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(Letters)

FRAME #2

The chief thing that makes algebra different from arithmetic is the use of letters instead of figures to represent numbers and to use these letters to form expressions and equations.

R: Instead of using figures to represent numbers, ________ are used.
These ________ are then used to form ________ and ________.

TURN TO PAGE 8

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FRAME #13

When two or more terms form an expression that is to be subjected to operations such as multiplication or division, they are enclosed in parentheses ( ), brackets [ ] or braces { }. These are called symbols of aggregation.

Example: If $4X$ is to be multiplied by $2a + b$, the expression is written $4X(2a + b)$

The parentheses show us that we are multiplying the expression $2a + b$, as a whole, by the term $4X$. The expression $(a)[4-b(a-b)]$ indicates that the difference between $a-b$ is to be multiplied by b and the product of this subtracted from 4 before it is multiplied by a.

R: The three symbols of aggregation are ________, ________ and ________

GO TO PAGE 9

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FRAME #3

When figures are used to express a mathematical situation, the expressions obtained refer to specific cases.

R: Figures limit the expressions obtained to ________ ________.

GO TO PAGE 10

(Parentheses) (Brackets) (Braces)

FRAME #14

When the root of a quantity is extracted, the sign $\sqrt{\quad}$, called the radical sign is used, together with a small figure known as the index of the root.

Example: Some of the radical signs used are:

(1) Square root $\sqrt{\qquad}$
(2) Cube root $\sqrt[3]{\qquad}$
(3) Any root $\sqrt[N]{\qquad}$

Any number can be substituted for N.

R: The radical sign that shows the cube root of a number is __________

T: The square root is __________, and to show any root of a number is __________.

GO TO PAGE 11

FRAME #4

The basic concept which we shall add to our previous knowledge of math is the idea of a general number; that is, the representation of numbers by letters.

Example: We say that a room is x feet long and x may stand for any number. If we are speaking of a particular room and measure it to be 10 feet long, then x would equal 10; however, for a different room x may have a different value.

R: The representation of numbers by letters is accomplished by using the concept of a ______ __________.

GO TO PAGE 12

FRAME #15

In algebraic addition there are three cases which must be taken into account; they are:

(a) Positive number plus positive number
(b) Positive number plus negative number
(c) Negative number plus negative number.

Example: (a) To add two or more positive numbers, find the sum of their absolute values and prefix to this sum the positive sign. Hence, add +7Y and +6Y, the product equals +13Y.

(b) To add a positive number and a negative number, find the difference of their absolute values and prefix the sign of the larger number to the result. Hence, add –9ax to +3ax, the product equals –6ax.

(c) To add two or more negative numbers, find the sum of their absolute values and prefix to their sum the minus sign. Hence, add –9x to –6x, the product equals –15x.

Action: **Add:**

$$\begin{array}{rrrr} +25xy & -37a & -43bc & +20\,b \\ +18xy & +22a & -37bc & -50\,b \\ \hline \text{-------} & \text{------} & \text{------} & \text{-------} \end{array}$$

GO TO PAGE 13

FRAME #5

When two or more quantities are multiplied together, each quantity is called a factor of the product.

Example: If 4, 6 & 8 are multiplied together the product is 192; then 4, 6 & 8 are factors of 192, but since 4 × 6 is 24 and 24 × 8 is 192, then 24 and 8 are also factors of 192.

R: If the product of 3 × 4 × 6 is 72, the factors of 72 are ____, ____, ____

GO TO PAGE 14

(+43xy), (−15a), (−80bc), (−30b)

FRAME #16

One general rule is sufficient to cover all cases of algebraic subtraction. Change the sign of the subtrahend, and then add the altered subtrahend to the minuend, using the rules for algebraic addition. In the above rule, the subtrahend is the quantity to be subtracted and the minuend is the quantity that it is to be subtracted from.

Example: To subtract −4ab from +8ab, change the sign of the subtrahend (−4ab), and then add to the minuend (+8ab), the algebraic sum equals +12ab.

Action: **Subtract:** +3a from +5a
−2x from +3x

GO TO PAGE 15

FRAME #6

In any expression that represents a product, any one of the factors, or the product of any two or more of them, may be regarded as the coefficient of the remaining part of the expression.

Example: If the quantity 7abc is considered, 7 is the numerical coefficient of abc, 7a is the algebraic coefficient of bc and 7ab is the algebraic coefficient of c.

R: If the quantity 5xy is considered, 5 is the_____ _____ of xy and 5x is the __________ __________ of y.

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(+2a), (+5x)

FRAME #17

In multiplication of algebraic terms, the product of two numbers having like signs is a positive number and the product of two numbers having unlike signs is a negative number.

Example: (a) multiply +8x by +4x, can be written as (8x)(4x), the algebraic product equals $32x^2$.

(b) The product of $(-8x)(4x) = -32x^2$.

Action: a. Find the product of (2a)(6a)

b. Find the product of (−3b)(3b).

GO TO PAGE 17

(Numerical Coefficient) (Algebraic Coefficient)

FRAME #7

An exponent is any number or algebraic expression written at the right of, and above, another number or algebraic expression to show how many times the latter is to be taken as a factor.

Example: **If 4 is multiplied by itself, we say we have squared 4 (written as 4^2). If a is multiplied by itself we express it as a^2.**

R: **The exponent of any number or expression will be placed at the __________ of, and __________ that number or expression.**

GO TO PAGE 18

$(12a^2)$, $(-9b^2)$

FRAME #18

In division of algebraic terms, the quotient of two numbers having like signs is positive and the quotient of two numbers having unlike signs is negative.

Example: (a) Find the quotient of $8x \div 2$. (Like signs) $8x \div 2 = 4x$.

(b) Find the quotient of $8x \div -2$. (Unlike signs) $8x \div -2 = -4x$.

Action: a. Find the quotient of $32x \div 4$.

b. Find the quotient of $32x \div -4$.

GO TO PAGE 15

(Right) (Above)

FRAME #8

The number whose power is to be found is called the base number.

Example: In the expression a^3, a is the base number and 3 is the power of the base number that is desired.

R: In the expression X^2, X is the __________ __________ and ^{2} is the __________ of the base number.

GO TO PAGE 20

(8x), (-8x)

FRAME #19

An algebraic equation is a statement of equality between two quantities or operations. Equations are a very convenient means of expressing the relationship between known and unknown quantities. An equation of this type is called a formula.

R: A formula can also be referred to as an ________ ________

GO TO PAGE 21

(Base Number) (Power)

FRAME #9

When multiplying quantities having the same base numbers, their exponents are added, and when dividing quantities having the same base numbers, their exponents are subtracted.

Example: If we were to divide a^4 by a^2, we would subtract 2 from 4, giving us a final result of a^2. If however, we had been multiplying, a^4 by a^2, we would have obtained a result of a^6.

R: The exponents are ________ when dividing quantities which have the same base numbers, and ________ when multiplying quantities having the same base numbers.

GO TO PAGE 22

FRAME #20

The quantity that, when substituted for the unknown quantity, reduces an equation to an equality is said to satisfy that equation.

Example: $x + 9 = 11$ is satisfied when the value 2 is substituted for the unknown x

Action: Satisfy the following equations:

a. $9 + x = 15$ $x =$ ______

b. $x - 15 = 12$ $x =$ ______

GO TO PAGE 23

(Subtracted) (Added)

FRAME #10

An algebraic expression may consist of parts which are separated by the + and − signs; these parts with signs immediately preceding them are called terms.

> **Example:** The expression $3X - 4Y + Z$ is separated by the plus or minus sign into three parts, $+3X$, $4Y$, $+Z$. These parts are the terms in the expression.

R: If an algebraic expression is separated into parts by the + or the − signs, these parts are called the __________ of the expression.

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(6) (27)

FRAME #21

The form of an equation may be changed, when solving an equation, but the change must be such that the sides remain equal to each other after the change. The same change must be made in both sides so they remain equal. The change in the form of an equation in this manner is called transformation. Four commonly used ways of transformation are:

(a) By adding the same quantity to both sides of the equation.

Example:
$$\begin{array}{r} 2x + 10 = 16 \\ 5 = 5 \\ \hline 2x + 15 = 21 \end{array}$$

(b) By subtracting the same quantity from both sides of the equations.

Example:
$$\begin{array}{r} 2x + 10 = 16 \\ -\ 5 = -5 \\ \hline 2x + 5 = 11 \end{array}$$

(c) By multiplying both sides of an equation by the same quantity, or by raising both to the same power.

Example:
$$\begin{array}{r} 2x + 10 = 16 \\ (2x + 10)^2 = (16)^2 \\ 4x^2 + 40x + 100 = 256 \end{array}$$

$$\begin{array}{r} (2)\ (2x + 10) = (2)\ (16) \\ 4x + 20 = 32 \end{array}$$

(d) By dividing both sides of an equation by the same quantity, or by extracting the same root of both sides.

Example: $\frac{2x + 10}{2} = \frac{16}{2}$ or $x + 5 = 8$

R: The value of each side of the equation is changed by any form of ____________, but the sides still remain equal and the value of the unknown is not altered.

GO TO PAGE 25

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FRAME #11

If an expression contains only one term it is said to be a **monomial**; if it has two terms it is a **Binomial**, and if it has many terms it is a **Polynomial**.

Example: The expression 5X has only one term, so therefore it is a monomial expression; if however, the expression had two terms, 5X + 5Y, it would be a binomial expression, and if it had more than two terms, 5X + 5Y 5A, it would be a polynomial expression.

R: A one term expression is said to be _________, an expression with two terms is a _________ expression, and an expression with many terms is a _________ expression.

GO BACK TO PAGE 5 AND CONTINUE WITH FRAME #12

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FRAME #22

Transposition is the process of taking a term from one side of an equation and placing it in the other side of the equation with the sign changed. It is equivalent to adding the same quantity to, or subtracting the same quantity from, both sides of the equation.

Example: $6x + 4 = 2x + 3$.

The 2x can be brought to the left side of the equation by dropping it from the right side and writing it in the left side with the sign changed. Now the equation reads: $6x - 2x + 4 = 3$ or $4x + 4 = 3$.

Action: Transpose 15x in the following equation: $23x - 4 = 15x + 4$

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$(23x - 15x - 4 = +4)$ or $(8x - 4 = +4)$

FRAME #23

The following is a precise statement of what to do in solving the simple equation:

(1) Transpose all the terms containing the unknown to one side of the equation.

(2) Transpose all the terms not containing the unknown to the other side of the equation.

(3) Divide both sides of the equation by the coefficient of the unknown.

R: After transposing all terms containing the unknown to one side and all terms not containing the unknown to the other side, both sides are then ____________ by the coefficient of the unknown.

GO TO PAGE 27

(Divided)

You have now completed the "Lesson Frames". Now complete the review which is in the form of a self-test. Fill in the blank spaces in each test item. The number in parenthesis ( ) located at the right of each blank space refers you to the frame number from which the statement was taken.

TURN TO NEXT PAGE

SELF-TEST

1. Algebra is that part of math which employs letters in reasoning about __________ (1).

2. When numbers are used in solving an algebraic expression, the expression will be pertaining to a __________ (3) case; whereas, if letters are used the expression will be pertaining to a __________ (4) case.

3. In the expression 4 × 9 × 20, 4, 9 and 20 are __________ (5) of the product 720.

4. The number written to the right of, and above another is called the _______ (7) of that number.

5. If 5 is multiplied by itself, we have __________ (7) 5 . It is expressed as __________ (7)

6. The terms of an expression are parts which are separated by the __________ (10) and __________ (10) signs.

7. The absolute value of a number is its value without regard to the __________ (12) before it.

8. The three symbols of aggregation are __________, __________ and __________ (13).

9. The radical sign for the cube root of a number is __________ (14).

10. The prefix to the sum of a positive number added to a positive number is the __________ (15) sign.

11. The prefix to the sum of a positive number added to a negative number is the sign of the __________ (15) number.

12. The product of two numbers having like signs is a __________ (17) number and the product of two numbers having unlike signs is a __________ number.

13. Equations are also called __________ (19).

14. When making a change in the form of an equation, the sides must remain __________ (21).

15. The process of taking a term from one side of the equation and placing it in the other side is called __________ (22).

[illegible]
[illegible]

PROGRAMMED LESSON

POWERS AND ROOTS

NOVEMBER 1973

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

POWERS AND ROOTS

Programmed Text

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INTRODUCTION

Of all the mathematical processe we learn in school perhaps the easiest to forget are the uses of powers and roots. Problems involving powers and roots rarely occur in everyday life and unless you are in one of the scientific fields you seldom use them. Since they are critical in the field of surveying we find it necessary to review the basic fundamentals

This text is designed as a review and when successfully completed should provide the student with sufficient background to solve any problems that required the use of positive whole number exponents and square roots.

POWERS AND ROOTS

INSTRUCTIONS TO STUDENTS

This program text is a unit of work which involves "Self Teaching". The overall lesson information is broken into small steps called "frames". Each frame instructs with words, sample problems, or both, then requires you to apply that bit of instruction by completing a response or doing a described action. The booklet is set up so the frame is on the front of the page; while the response or illustrative portion of that frame is on the back of the page.

To work and learn with this booklet, you read the frame and complete the response or problem, then continue over to the back of the page for the answer, it is there for verification, NOT for COPYING. When that frame is completed successfully, go to the next frame in numerical sequence.

This lesson may be given as a classroom exercise or it may be given as a homework assignment. If you are in the classroom and find that you need assistance or advice in order to arrive at the correct answer raise your hand and an instructor will assist you. If the exercise is given as a homework assignment and there is no instructor available to assist you in arriving at the correct answer, go back and review the previous frames, you may have missed a point. Otherwise, continue to the next frame.

POWERS AND ROOTS

OBJECTIVES OF THIS LESSON

Upon completion of this text you should be able to:

1. Define a factor.
2. Define a base.
3. Define a power.
4. Define an exponent.
5. Indicate the power to which a number is to be raised using exponents.
6. Raise any given number (base) to any given power.
7. Define a root.
8. Draw a radical and describe its use.
9. Define an index.
10. Indicate the root to be extracted using the radical and index.
11. List perfect squares up to 100 and their square roots.
12. Identify and put in proper sequence the steps used to extract a square root.
13. Extract the square root of any given whole number, decimal number, or common fraction.
14. Evaluate your solution by squaring your solution and adding the remainder.

1. A factor of a given number is any number that will divide into that number exactly. In the following problem 7 and 5 would be called ____________ of 35.

$$\begin{array}{r} \underline{7} \\ 5/35 \\ \underline{35} \\ 00 \end{array}$$

28. If we wanted to indicate the number of times a base is to be used to obtain a power and, if we had to write it out long hand: i.e. 3 x 3 x 3 x 3 = 81 or, use 3 as a base 4 times, it would take all day and reams of paper to write a few problems. Instead we use a numerical symbol called an exponent to indicate how many times the base is taken as a factor.

55. In the last frame there was no decimal point indicated, and there was an even number of digits, now lets look at another case, one with an odd number of digits to the right and left of the decimal, for example 437.0 which would be separated as 4'37.'00. Separate the number 54,723.111 into periods ________ ______________.

1. Factors

28. No response required

55. 5'47'23.11'10
As we know we can add a zero to the left (front) of a whole number (054723.111) without changing its value. We can also add a zero to the right (back) of a decimal without changing its value. Since the zero on the left of the whole number will not be used it need not be written. However, the zero on the right of the decimal will be used and must be shown.

2. Complete the following problem: 34 ÷ 2 =

The factors in the problem given above are ______________ and ________________.

29. An exponent is a numerical symbol indicating the power to which a base is to be raised. A positive whole number exponent indicates the number of times the ______ is to be used as a _____________. The result of this multiplication is called the ________________.

56. The number of periods formed, both to the right and to the left of the decimal point, will equal the number of digits in the answer both to the right and the left of the decimal. For example the square root of 1 00 is $\overset{1\ 0}{\sqrt{1'00}}$

however, the square root of 1.00 is $\overset{1.0}{\sqrt{1.00}}$. There are ______ digits in the square root of 58081.00.

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2. 2, 17

29. Base, factor, power

56. 4, The square root of 58081.00 is 241.0 or 4 digits

3. If 17 is one factor of 51 the other factor is ____________.

30. The exponent is written as a small number placed above and to the right of the base. Given 3^4, 3 is called the __________ and 4 is the ______________.

57. The second step in finding a square root is to find the largest perfect square which is equal to, or less than the left hand period. In the sample below this perfect square is 9. Write it under the first period (11) and place it's root (3) above the first period in the answer.

Example:

$$\begin{array}{l} \overline{\;\;3\;\;\;\;\;\;\;\;\;\;\;} \\ \sqrt{11'62'81} \\ \;\underline{\;9\;} \end{array}$$

3. 3

30. 3 = base
    4 = exponent

57. No response

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4. Another method of indicating division is to write the problem in fractional form. Perform the division indicated in the following problem ½ = ________________. In the problem above the factors are ________________ and ______________. The product of the factors is ___________________.

31. If the base 5 is to be used 7 times as a factor the statement would be written ________________ using exponents.

58. Step three is to subtract the perfect square from the first period (11-9) and bring down the second period to form the first remainder.

$$\begin{array}{l} \ \ \ 3 \\ \sqrt{11'62'81} \\ \ \ \ \underline{9} \\ \ \ \ 262 \text{ -- first remainder} \end{array}$$

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4. .5
   2, .5, 1

31. 5^7

58. No response

5. It is possible for a number to have more than one set of factors for example in the number 16 we find the following facotrs:

$$\begin{array}{r} 4 \\ 4\overline{)16} \\ \underline{16} \\ 00 \end{array}$$

Therefore 4 is a factor of 16

$$\begin{array}{r} 8 \\ 2\overline{)16} \\ \underline{16} \\ 00 \end{array}$$

2 and 8 are factors of 16

32. In the problem 2 x 2 x 2 x 2 x 2; the base is used __________ times as a factor. The problem can be written as __________ using exponents and the resultant power (product) is ________.

59. Given the number 78961, divide the number into periods ________, the root of the first period is ______________ the first remainder is ______________. (NOTE: Be sure when bringing down a period to bring down both digits.)

$\sqrt{}$

5. No response

32. 5, 2^5, 32

59. $\begin{array}{ll} \overline{\ \ 2\qquad\ \ } & \text{root} \\ \sqrt{7'89'61} & \\ \underline{4} & \\ /389 & \text{-- first remainder} \end{array}$

6. One set of factors for the number 30 is 2 and 15. Another set of factors for 30 is ______________ and ____________.

33. Given 3 x 3 x 3 x 4 x 4 = ____________ we would rewrite the problem as _________ x ______________ using exponents. The resultant product is _______________.

60. Step four is to determine a trial divisor. To do this, multiply the answer (root) obtained so far (3) by 20 (3 x 20 = 60) and write it to the left of the first remainder. (NOTE: It is not necessary to write in the zero since it will be changed).

Example: $\overline{3}$

$\sqrt{11'62'81}$

$\underline{9}$

Trial - 60/ 262 -- first remainder
divisor

Find the trial divisor $\sqrt{625}$

6. 3, 10 or 5, 6 or 2, 3, 5

$3 \times 10 = 30$
$5 \times 6 = 30$
$2 \times 3 \times 5 = 30$

33. $3^3 \times 4^2$; 432

60.
$$\begin{array}{rl} & \;\;2 \\ & \sqrt{6'25} \\ & \;\;\underline{4} \\ 4\underline{0}/ & \overline{2}25 \end{array}$$

7. Two factors of the number 27 are __________ and __________.
Are there any other possible factors? __________ / __________
YES NO

34. Given $2^2 \times 3^2 =$ __________ we can rewrite the problem as
__________ x __________ x __________ x __________ =
and the resultant product is __________.

61. Find the first digit of the root, the first remainder, and the first trial divisor for the number 223.0.

7. 3, 9
NO, 3 x 3 x 3 = 27 but 3 has already been named as a factor

34. 2 x 2 x 3 x 3 = 36

```
      1
61. √2'23.00
      1
   20/123
```

8. A factor of a given number is ____________ ________ that will divide into that number ____________.

35. Since the exponent indicates the power to which the base is to be raised we read the exponents as the power. For example 3^4 would read, or be stated as: three to the fourth power. 5^6 would be stated as _________ to the ________ power.

62. For step five divide the remainder by the trial divisor. The result of this division is the next figure in the root. It is also used to replace the zero on the right of the trial divisor to form the divisor. Multiply this divisor by the last digit of the root, and place the product under the remainder. If the product is equal to, or less than, the remainder you have found the true divisor. Subtract the product from the remainder and bring down the next period to form a new remainder. This process is repeated for each figure in the root or until the desired number of decimal places have been reached. Find the square root of 625.

8. Any number, exactly

35. five to the sixth or 5 to the 6th

```
       2  5
62.  √6'25
       4
   45/225
      225
```

If you got it go to the next frame if not review frames 51, 52, 55, 56, 58 and 60.

9. If we examine the definition of a factor, we will find that a factor of a number may also be defined as any one of two or more numbers which when multiplied will produce the given number. In the sample problem below 2,3,5 and 7 are all factors of 210.

$2 \times 3 \times 5 \times 7 = 210$

36. Some exponents, or powers, have special names. The second power of a number is called the square. 3^2 would be read 3 squared. The third power of a number is called the cube, written 3^3 and read as 3 ____________.

63. Solve: $\sqrt{324}$

187

9. No answer required

36. cubed

63.
```
   1 98    =   18
 8/3'24
 9 1
20/224
   261
   224
   000
```

NOTE: the first product was too large and the last digit of both the divisor and the root had to be changed.

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10. In the following problem the missing factor is __________.

2 x 3 x __________ = 66

37. The power (product) 16 could also be expressed as 2 to the __________ power or __________ using exponents.

64. Solve: $\sqrt{3025}$

10. 11

37. fourth, 2^4
If you got it go on, if not see frames 12, 33 and 34.

64.
$$\begin{array}{r l} & \phantom{\sqrt{}}\overline{\;5\;\;\;\;5\;} \\ & \sqrt{30'25} \\ & \phantom{\sqrt{}}\underline{25} \\ 10\underline{5}/ & \phantom{\sqrt{}}\;525 \\ & \phantom{\sqrt{}}\;\underline{525} \\ & \phantom{\sqrt{}}\;000 \end{array}$$

11. Referring back to Frame 5 we know that 2, 4 and 8 are all factors of 16. Using the definition in Frame 9 we can see that this fact may also be stated as : 4 x 4 = 16 and 2 x 8 = 16, this being true we can also say that 2 x 2 x 2 x 2 = 16. Therefore 2 is the smallest possible factor of 16.

38. The problem four squared plus three cubed plus two to the fourth power would be rewritten ____________ + __________ + ____________ = and the result is ______________.

65. Solve: $\sqrt{13225}$

11. No answer required

38. $4^2 + 3^3 + 2^4 = 59$

Result $= 4 \times 4 + 3 \times 3 \times 3 + 2 \times 2 \times 2 \times 2 = 16 + 27 + 16 = \underline{59}$

65.

$$\begin{array}{rl} & \overline{1\;\;1\;\;5} \\ & \sqrt{1'32'25} \\ & \underline{1} \\ 2\underline{1}/ & 32 \\ & \underline{21} \\ 22\underline{5}/ & 1125 \\ & \underline{1125} \\ & 0000 \end{array}$$

12. Two factors of the number 81 are ________ and ________. By finding the factors of these factors we can find that ________ x ________ x ________ x ________ = 81.

39. An exponent is a numerical symbol indicating a/the ________ ________________________________. (in your own words)

66. Solve: $\sqrt{28224}$

12. 9, 9 or 3, 27
9 = 3 x 3 so 9 x 9 = 3 x 3 x 3 x 3
27 = 3 x 9 or 3 x 3 x 3 so 3 x 27 = 3 x 3 x 3 x 3

39. A power, or the number of times a base is used as a factor.

66.
```
         1  6  8
       √2'82'24
        1
     26/182
        156
    328/ 2624
         2624
         0000
```

13. Using the logic presented thus far the smallest possible factors of 105 are __________, ____________ and ___________.

40. The nth root of a number is that number (base) which when used as a factor n times will produce the number. The square root of a number is one of two equal factors into which a number is divided. The cube root is one of three equal factors into which a number is divided; the fourth root is one of four equal factors; and so on for the higher roots.

67. If at any time the trial divisor is larger than the corresponding remainder place a zero in the root and at the right of the trial divisor then bring down the next period.

Example:

$$\begin{array}{rr} & 2\ \ 0\ \ 5 \\ & \sqrt{4'20'25} \\ & \underline{4\qquad\quad} \\ 4\underline{05}/ & 2025 \\ & \underline{2025} \\ & 0000 \end{array}$$

Solve: $\sqrt{95481}$

13. 3, 5, 7 (Logic see frames 11 and 12)

Solution 105 ÷ 5 = 21 so 5 and 21 are factors of 105
21 ÷ 3 = 7 so 3 and 7 are factors of 21

Substitute: 3 x 7 for 21 in first set of factors we have:
5 x 3 x 7 = 105

40. No response

67.

$$\begin{array}{rr} & \underline{3\;\;0\;\;9} \\ & \sqrt{9'54'81} \\ & \underline{9\;\;\;\;\;\;\;\;\;\;\;\;} \\ 6\underline{09}/ & 5481 \\ & \underline{5481} \\ & 0000 \end{array}$$

14. From what has been presented, can we say that all multipliers and multiplicans are factors of their product? ______/______ YES NO

41. If we separate the number 16 into two equal factors, 4 and 4 then one of these factors is called the root. Since the factor is used twice, or squared to obtain the number the factor is called the square root. A square root is a base which is used ________ times as a factor to obtain the given number.

68. Point off as many decimal places in the root as there are periods to the right of the decimal point in the original number.

$$\begin{array}{rr} & 1.2 \\ \text{Example:} & \sqrt{1.44} \\ & \underline{1} \\ 2\underline{2}/ & 44 \\ & \underline{44} \\ & 00 \end{array}$$

Solve: $\sqrt{16.5649}$

14. YES - If there is any doubt check frame 9

41. Two

```
          4. 0  7
68.     √16.56'49
         16
   807/    5649
           5649
           0000
```

15. Using what we have learned so far can we say that all divisors and quotients are factors of the dividend? ____________ / ____________
YES NO

42. The process of obtaining a root is just the inverse of that by which a power is found. Separating 125 into three equal factors 5 x 5 x 5 = 125 we would say that 5 is the ____________ root of 125, since the factor is used three times to obtain the power.

69. Solve: $\sqrt{25.20040}$

15. If you said YES you are WRONG! Remember they must divide exactly into the dividend. There are some combinations that just will not qualify. For example we can divide 3 into 10 all day long and when we stop there will still be a remainder.

```
   3.3 . . . . . .
3/10.0
  9
  10
   9
   1
```

42. Cube

69.

```
    5. 0  2  0
   √25.20'04'00 ← Add a zero to complete the last period
    25
1002/   2004
        2004
1004_/   0000
```

16. A factor of a number may be defined as ____________________ ________________________________. (State in your own words)

43. Again given the number 16 and knowing its two equal factors are 4 x 4 we can, by finding the factor of these factors, divide 16 into four equal factors of 2 x 2 x 2 x 2 = 16 when this has been completed we can say that 2 is the ________ root of 16 since the base 2 must be used four times as a factor.

70. Not all numbers are perfect squares. In a case where a problem does not come out even, we carry it out to one decimal place more than we desire and round the answer back to the desired number of decimals. Find the root of 123.4 to two decimals.

16. Anything that says: any number that will divide exactly into the given number or one of two or more numbers which when multiplied will produce the given number.

43. Fourth

70.
```
           1  1. 1  0  8      = 11.11
          √1'23.40'00'00
           1
     21/    23
            21
      221/  240
             221
   22208/   190000
            177664
              2336   remainder
```

17. A base is any factor which is multiplied by itself a given number of times to obtain a product. For example, in the problem 3 x 3 x 3 = 27. 3 would be called the ___________.

44. The radical sign, drawn √ , is used to indicate that a root is to be extracted. The radical is connected to a line (vinculum) which is drawn over the numbers to be affected. $\sqrt{123}$. A radical drawn as __________ indicates a __________ is to be found (taken).

71. Solve to three decimal places: $\sqrt{18}$

17. **Base**

44. √, root

71.

```
     4. 2  4  2  6   = 4.243
   √18.00'00'00'00
     16
 82/ 200
     164
844/  3600
      3376
8482/  22400
       16964
84846/  543600
        509076
         34524
```

18. Given the number 4 as a product and told to find a base factor. We must ask, what number times itself equals 4. The answer is ____________________.

45. A small figure called the index of the root, is placed in the opening of the radical sign $(\sqrt[3]{\ })$ to show what root is to be taken. The root to be taken is indicated by small figure called an ____________________.

72. Solve to three decimal places: $\sqrt{0.514089}$

18. 2

45. Index

72.
```
    0. 7  1  7     =    0.717
  √0.51'40'89
     49
141/  240
      141
1427/  9989
       9989
```

19. When a base is multiplied by itself a given number of times to obtain a product that product is called a power. If 6 is used 3 times as a base (factor) the resulting power is ________ x ________ x ________ =

46. Since the square root is most commonly used, the index number is omitted and the square root of 64 is written $\sqrt{64}$. Other roots must be shown by an index number.

$\sqrt[3]{8}$ indicates the ________ root of ________.
$\sqrt{144}$ indicates the ________ root of ________.
$\sqrt[6]{64}$ indicates the ________ root of ________.

73. Solve to four decimal places: $\sqrt{7.25}$

19. 216
6 x 6 x 6 = 216
36 x 6 = 216

46. Cube root of 8
Square root of 144
Sixth root of 64

73.
$$\begin{array}{rl}
 & \overline{2.\;6\;\;9\;\;2\;\;5\;\;8} = 2.6926 \\
 & \sqrt{7.25'00'00'00'00} \\
 & \underline{4} \\
46/ & 325 \\
 & \underline{276} \\
529/ & 4900 \\
 & \underline{4761} \\
5382/ & 13900 \\
 & \underline{10764} \\
53845/ & 313600 \\
 & \underline{269225} \\
538508/ & 4437500 \\
 & \underline{4308064} \\
 & 129436
\end{array}$$

20. If 12 is used two times as a base the resulting power is
______________ x ______________ = __________ .

47. The *n*th root of a number is ______________________________
____________________________. (In your own words)

74. To extract the square root of a common fraction first reduce the fraction to it's lowest terms then extract the square root of the numerator and of the denominator.

Example: $\sqrt{\frac{16}{64}} = \sqrt{\frac{1}{4}} = \frac{\sqrt{1}}{\sqrt{4}} = \frac{1}{2}$

Solve: $\sqrt{\frac{28}{112}} =$

20. 12, 12, 144

47. Any answer which means: that number which when used as a factor n times will produce the number.

74. $\sqrt{\frac{28}{112}} = \sqrt{\frac{7}{28}} = \frac{\sqrt{1}}{\sqrt{4}} = \frac{1}{2}$

21. The base factor of the number 36 is ____________. It is used 2 times as a factor.

48. A radical ($\sqrt{\ }$) indicates a ________ is to be found. If there is no index given (such as $\sqrt[3]{\ }$) the radical ($\sqrt{\ }$) indicates a ________ ________ is to be found.

75. If both terms of the fraction are not perfect squares, reduce the fraction to a decimal number and extract the square root of the decimal.

Example: $\sqrt{\frac{1}{5}} = \sqrt{1 \div 5} = \sqrt{.20'00}$

$$\begin{array}{rr} & \sqrt{.20'00} \\ & \underline{16} \\ 8\underline{4}/ & 400 \\ & \underline{336} \\ & 64 \end{array}$$

Solve to two decimal places: $\sqrt{\frac{3}{8}}$

21. 6, since 6 x 6 = 36
If you got it go on to frame 22. If you missed it see frames 17 and 18.

48. Root
Square root

75. $$\sqrt{\frac{3}{8}} = \sqrt{3 \div 8} = \overset{6\quad 1\quad 2}{\sqrt{.37'50'00}} = .61$$

$$\begin{array}{rr} & \underline{36} \\ 12\underline{1}/ & 150 \\ & \underline{121} \\ 122\text{-}/ & 2900 \\ & \underline{2444} \\ & 456 \end{array}$$

NOTE: Remember there must be an even period in the number for each decimal place in the root.

22. The base 4 is used __________ times to obtain the power 64.

49. An index placed in the radical indicates __________ __________ is to be taken.

76. Solve to four decimal places: $\sqrt{\frac{49}{169}}$

22. 3 times

(1) $\begin{array}{r}16\\4\overline{)64}\end{array}$ (2) $\begin{array}{r}\text{(3) } 4\\4\overline{)16}\end{array}$

$4 \times 4 \times 4 = 64$

$16 \times 4 = 64$

49. What root

76. $\sqrt{\frac{49}{169}} = \frac{\sqrt{49}}{\sqrt{169}} = \frac{7}{13}$ or .5384

23. The base factor of the power 8 is ____________. This base is used ________ times to obtain the power 8.

50. As the square root is the most frequently used and since the solution of the higher roots is, best and normally, performed using logarithms we will limit this text to the solution of square roots.

77. Solve to three decimals: $\sqrt{\frac{5}{9}}$

23. 2 use 3 times. $2 \times 2 \times 2 = 8$
$4 \times 2 = 8$

You got it? Go on to frame 24.
You didn't get it? See frames 9 - 12.

50. No response required

77. $$\sqrt{\frac{5}{9}} = \sqrt{5 \div 9} = \begin{array}{rl}
 & .7\;\;4\;\;5\;\;3 \\
 & \sqrt{.55'55'55'55} \\
 & \underline{49} \\
14\underline{4}/ & 655 \\
 & \underline{576} \\
148\underline{5}/ & 7955 \\
 & \underline{7425} \\
1490\underline{3}/ & 53055 \\
 & \underline{44709} \\
 & 8346
\end{array}$$

24. When all factors used in a multiplication are ________, that factor is called a base.

51. Before we begin the solution of square roots, we must know the squares of all numbers 1 through 10. These numbers are called perfect squares and are the only whole numbers up to 100, of which we can find the exact square root. Make a table of the numbers 1 through 10 and their squares.

Example: $1^2 = 1 \times 1 = 1$
$2^2 = 2 \times 2 = 4$

78. As in any other mathematical operation we have a method of checking our work. To check the accuracy of a square root you must square the root.

Example:
$$\begin{array}{rr} & \underline{1\ \ 2} \\ & \sqrt{1'44} \\ & \underline{1\quad\ } \\ 23/ & 44 \\ & \underline{44} \end{array}$$
check $12^2 = 12 \times 12 = 144$

Solve and check : $\sqrt{5476}$

24. Equal

51. $1^2 = 1 \times 1 = 1$
$2^2 = 2 \times 2 = 4$
$3^2 = 3 \times 3 = 9$
$4^2 = 4 \times 4 = 16$
$5^2 = 5 \times 5 = 25$
$6^2 = 6 \times 6 = 36$
$7^2 = 7 \times 7 = 49$
$8^2 = 8 \times 8 = 64$
$9^2 = 9 \times 9 = 81$
$10^2 = 10 \times 10 = 100$

78.
$$\begin{array}{rl} & \overline{7\quad 4} \\ & \sqrt{54'76} \\ & \underline{49} \\ 144/ & \overline{576} \\ & \underline{576} \end{array}$$

Check 74^2

$$\begin{array}{r} 74 \\ \underline{\times\ 74} \\ 296 \\ \underline{518\ } \\ 5476 \end{array}$$

25. A power is the product of ________ or __________ equal numbers.

52. Having constructed the table of perfect squares answer the following from memory.

$\sqrt{64}$ $\sqrt{25}$ $\sqrt{81}$ $\sqrt{49}$

79. Since all numbers are not perfect squares we must have a means of checking those numbers which do not come out evenly. To do this we square the root (before rounding off) and add the remainder.

```
                8. 4
Example:      √72.00          Check        8.4
               64                        x 8.4
         164/  800                         336
               656                        672
               144   Remainder            7056
                                         + 144
                                          72.00
```

Solve to one decimal and check: $\sqrt{75}$

25. Two or more

52. 8, 5, 9, 7

```
                8. 6           Check      8.6
79.           √75.00                    x 8.6
               64                         516
            166/1100                     688
               996                       7396
               104                     + 104
                                         7500
```

26. The base factor of the power 27 is __________. This base is used ________ times as a factor to obtain the power 27.

53. The first step in the process of extracting the square root of a number is to separate the number into periods of two digits each. The first step in extracting a square root is to "prepare the number" by dividing it into _________ of ______ ___________ each.

26. 3, 3
3 x 3 x 3 = 27

53. Periods, Two digits

27. The smallest possible base factor of 64 is __________.
This factor is used __________ times to obtain the power 64.

54. To separate the number, start at the decimal point and work both ways, placing an apostrophe (') after each two digits. For example the number 1,600 would be separated into two periods 16'00. Separate the number 103,041 into periods of two digits ________________.

27. 2, 6 times
64 = 2 x 32
64 = 2 x 2 x 16
64 = 2 x 2 x 2 x 8
64 = 2 x 2 x 2 x 2 x 4
64 = 2 x 2 x 2 x 2 x 2 x 2

GO BACK TO PAGE 1 FOR FRAME 28

54. 10'30'41

GO BACK TO PAGE 1 FOR FRAME 55

SELF-TEST

These self-test questions are provided to give you practice in using the information that you have learned from your study of this text. The answer to each written question is found in the frame in the text where the information was discussed. The answers for mathematical problems must be checked by the student, using the check methods taught in the text. After completing all the questions, check your work by refering to the appropriate frame. If you made an error re-read the frame and correct the answer.

	QUESTIONS	FRAME
1.	A factor of a given number is __________ that will divide into that number ________.	F-1
2.	An exponent is a numerical symbol indicating ______________________________________.	F-26
3.	A radical drawn ____________ and used without an index indicates __________________.	F-42 & 44
4.	A base factor is any factor which is ______ __________ by _________________ a given number of times to obtain a power.	F-17
5.	Using exponents indicate the following powers:	
	a. Five to the sixth power = ____________ .	F-28
	b. Seven cubed = ________________.	F-34
6.	When an index is used with a radical it indicates _______________________________.	F-43
7.	When all factors used in a multiplication are equal the result is called a _________ ____________ ____________.	F-19
8.	Two to the sixth power equals ____________.	F-30
9.	Using a radical and an index indicate the fifth root of sixty-five.	F-43
10.	A square root is one of ______________ factors into which a number is divided.	F-38

(QUESTIONS Cont'd)

FRAME

11. Indicate using number 1 through 5 the proper sequence for the following operations when extracting a square root.

F-51 thru 60

a. Divide the remainder by the divisor ________________.

b. Find the largest perfect square which is less than, or equal to, the first period ________________.

c. Determine the trial divisor ____________.

d. Find the first remainder ______________.

e. Separate the number into periods of two digits each ______________.

12. Square all numbers 1 through 15. Check your work by dividing by a factor.

a. 1 x 1 =
b.
c.
d.
e.
f.
g.
h.
i.
j.
k.
l.
m.
n.
o.

13. Solve and check the following problems to two decimals.

a. $\sqrt{288}$

b. $\sqrt{\frac{7}{8}}$

c. $\sqrt{\frac{9}{16}}$

d. $\sqrt{1.526}$

e. $\sqrt{.05632}$

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[illegible]

ENGINEER MAPPING SCHOOL – FORT BELVOIR, VIRGINIA

The sides of a plane triangle are so related that any three given parts, at least one of them being a side, determine the shape and size of the triangle.

Geometry shows us how, from three such parts, to CONSTRUCT the triangle.

TRIGONOMETRY shows us how to compute the unknown parts of a triangle from the numerical values of the given parts.

Geometry shows in a general way that the sides and angles of a triangle are mutually dependent.

Trigonometry starts by showing the exact nature of this dependence in the RIGHT TRIANGLE, and for this purpose employs the RATIOS OF THE SIDES.

1a. The shape of any triangle is determined by any ___________ given parts, at least one being a ___________.

1b. ___________ shows us how to construct the triangle.

1c. Trigonometry teaches us how to ___________ for the unknown parts of a triangle.

1d. To show the nature of the mutual dependency of sides and angles in a right triangle trigonometry uses the ___________ of the ___________.

1a. three, side

1b. Geometry

1c. compute

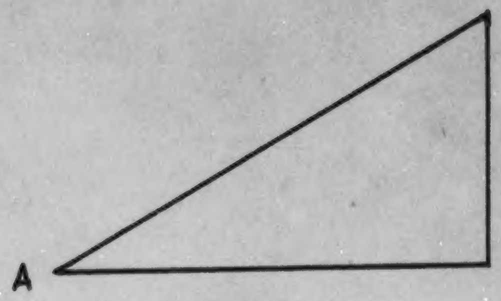
1d. ratios, sides

2. In order to keep the labeling of the various parts of triangles consistent, we label the angles in capital letters (A,B,C) and the sides in lower case letters to coincide with their opposite angles (a,b,c).

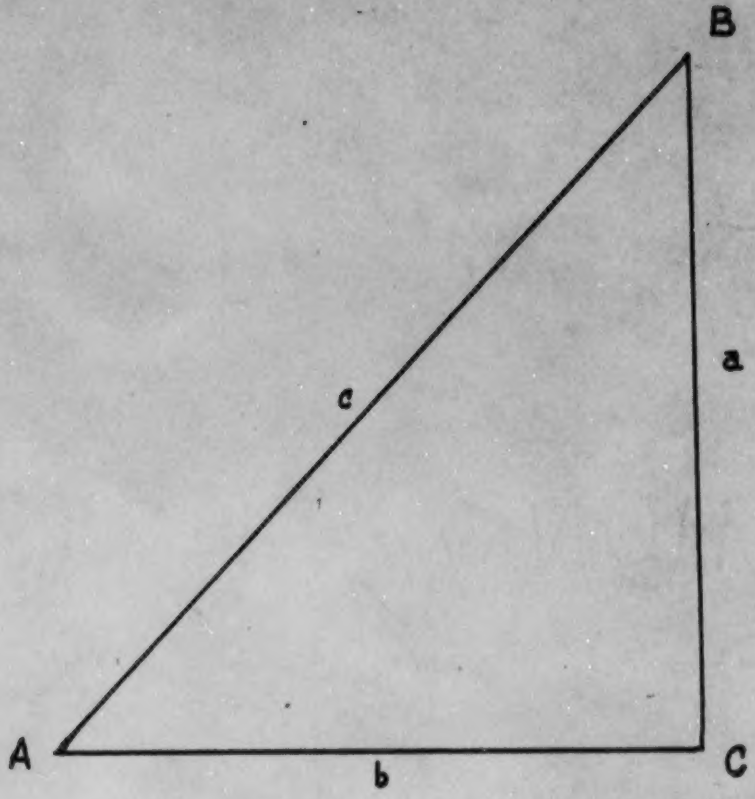
Normally we label the right angle as C making the side opposite the right angle c.

Also, in right triangles the side opposite the right angle is called the hypotenuse.

Given right triangle ABC label the sides and angles.



2.



3. The angle opposite side b is ____________.

3. B

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4. The Pythagorean Theorem states that the sum of the squares on the sides of a right triangle is equal to the square on the hypothenuse.

Using our established method of lettering of the parts of a right triangle we can state that c^2 = ________________

and c = ________________

245

4. $c^2 = a^2 + b^2$

$c = \sqrt{a^2 + b^2}$

5. Using the same theorem we can state that b = ______________ and

a = ______________.

5. $b = \sqrt{c^2 - a^2}$

$a = \sqrt{c^2 - b^2}$

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6. In right triangle ABC: a = 6, b = 8. What is the value for c?

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6. 10

7. In right triangle ABC: c = 10, b = 6. What is the value for a?

7. 8

8. In order to facilitate easy reference to the various functions, Trigonometry uses the following ratio designations:

a. The ratio of the side opposite to the hypothenuse is called the sine (sin).

b. The ratio of the adjacent side to the hypothenuse is called the cosine (cos).

c. The ratio of the opposite side to the adjacent side is called the tangent (tan).

d. The ratio of the adjacent side to the opposite side is called the cotangent (cot).

e. The ratio of the hypothenuse to the opposite side is called the cosecant (csc).

f. The ratio of the hypothenuse to the adjacent side is called the secant (sec).

8. (Blank)

9. The ratio of the opposite side to the adjacent side is called the ________________.

9. tangent

10. The cosine is the ratio of the __________ to the __________.

10. adjacent - hypothenuse.

11. The cotangent is the ratio of the __________ to the __________.

11. adjacent - opposite

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12. In trigonometry we call the various ratios _______________.

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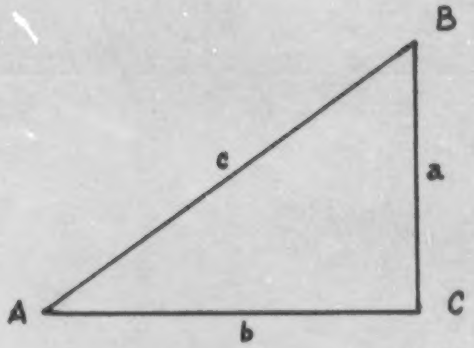
12. Functions

13. Let us look at a properly drawn and labeled right triangle:



and using the letter designations of the various parts, set up the formulas for the different functions of the angles.

sinA =	sinB =
cosA =	cosB =
tanA =	tanB =
cotA =	cotB =

13. $\sin A = \frac{a}{c}$ $\sin B = \frac{b}{c}$

$\cos A = \frac{b}{c}$ $\cos B = \frac{a}{c}$

$\tan A = \frac{a}{b}$ $\tan B = \frac{b}{a}$

$\cot A = \frac{b}{a}$ $\cot B = \frac{a}{b}$

14. Looking at your answers to the preceding question (13), compare the different functions for angles A and B. You will find out that

sinA = ____________B

cosA = ____________B

tanA = ____________B

cotA = ____________B

14. sin A = cos B

cos A = sin B

tan A = cot B

cot B = tan B

15. In Geometry we learned that the sum of all angles in any triangle is 180°, and that a right angle has 90°.

We can therefore state that the sum of angles A and B is ____________________.

15. 90°.

16. We can also state that sin A - cos (90° - ________)

cos A = sin (90° - ________)

tan A = cot (90° - ________)

and cot A = tan (90° - ________)

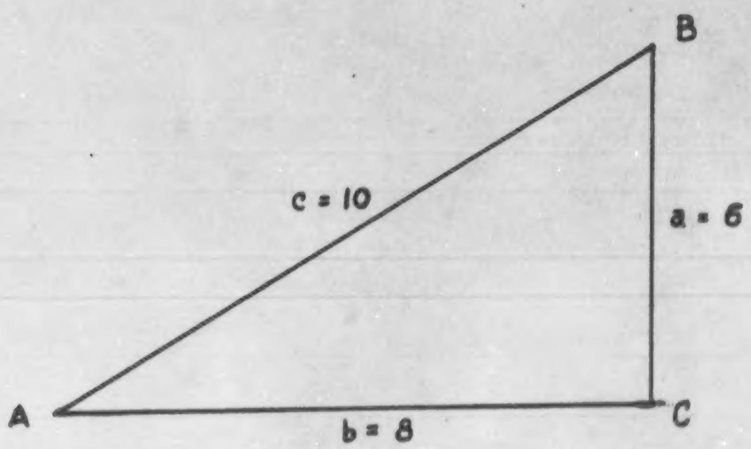
16. $\sin A = \cos (90^\circ - A)$

$\cos A = \sin (90^\circ - A)$

$\tan A = \cot (90^\circ - A)$

$\cot A = \tan (90^\circ - A)$

17. Given right triangle ABC, with $a = 6$, $b = 8$, and $c = 10$, find the values for the functions of angles A and B.


B
c = 10
a = 6
A
b = 8
C

17. $\sin A \frac{6}{10} = \frac{3}{5} = 0.60$

$\cos A \frac{8}{10} = \frac{4}{5} = 0.80$

$\tan A \frac{6}{8} = \frac{3}{4} = 0.75$

$\cot A \frac{8}{6} = 1\frac{1}{3} = 1.3333$

and of course, $\sin B = 0.80$

$\cos B = 0.60$

$\tan B = 1.3333$

$\cot B = 0.75$

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18. The values obtained in the preceding answers are:
a. arithmetical, b. logarithmic values for the various
functions. (cross out one)

18. arithmatical

19. SELF TEST

a. The Pythagorean Theorem tells us that

$a^2 =$ ____________

$b^2 =$ ____________

and $c^2 =$ ____________

b. The ratio of the opposite side to the hypothenuse is called the ________________.

c. The cosine of angle A = ____________. (use sides a,b, and c).

d. sin A = cos ____________.

e. Given: $a = 4$, $b = 7$. What is the value for tan A?

f. Given $a = 12$, $c = 32$, what is the value for sin A?

19. SELF TEST

a. $a^2 = c^2 - b^2$

$b^2 = c^2 - a^2$

$c^2 = a^2 + b^2$

b. sine

c. $\frac{b}{c}$

d. $\cos(90^\circ - A)$

e. $\frac{4}{7}$ or .57143

f. $\frac{3}{8}$ or .3750

20. In order to determine the angle of a triangle when we are given the numerical value of its function, we need a table of Natural Trigonometric Functions. There are many such tables but we shall discuss only those published in TM 5-236 (Table III).

If we look at the pages of these tables, we see, at the top, the degrees (°) columns for sin, tan, cot and cos. If we read the degree on top, we use the columns on top of the page and the minute (') column down the left side of the page. This procedure is valid for angles up to 45°. For angles over 45° (45° to 90°), we read and use the degree and function columns on the bottom, and use the minute column going up the right side of the page. Between the functions columns are the columns listing the differences per one second (d"). This difference per second, multiplied by the number of seconds above the listed angle (° and ') is added to or subtracted from this listing -- added when dealing in sin and tan, where values increase as the angle increases; subtracted when dealing in cos and cot, where values decrease as the angle increases.

20. (blank)

21. Let us now look up the natural functions of a few angles (using the tables in TM 5-236). We find that the

sine of 17° = 0.292372

cos of 17° = 0.956305

tan of 17° = 0.305731

cot of 17° = 3.27085

Also sin 24° 20' = 0.412045

sin 24° 20' 15" = .412045

+ 66 (4.42 x 15 = 66.3)

sin 24° 20' 15" = 0.412111

Now find: sin 33° 10'

tan 36° 20'

sin 39° 28' 33"

tan 44° 32' 27"

21. $\sin 33^\circ 10' = 0.547076$

$\tan 36^\circ 20' = 0.735469$

$\sin 39^\circ 28' 33'' = 0.635753$

$\tan 44^\circ 32' 27'' = 0.984099$

22. Find the following values:

sin 47° 25'

sin 54° 32' 28"

tan 74° 10' 20"

tan 84° 15' 10"

22. sin 47° 25' = 0.736294

sin 54° 32' 28" = 0.814532

tan 74° 10' 20" = 3.527397

tan 84° 15' 10" = 9.9359

23. a. As stated earlier: The values of the cosine and cotangent functions decrease as the angle increases. Let us now look up the cosine of 27° 15' 30". We find cos 27° 15' to be 0.889017. The cos 27° 16' is 0.888884 (or 133 less than the cos of 27° 15').

Now we put down. cos 27° 15' 00" 0.889017

- difference for 30" (30 x 2.22) - 67

Hence cos 27° 15' 30" 0.888950

The same procedures are followed when determining cotangents.

b. Find cos 29° 20' 10"

cos 74° 15' 15"

cot 89° 15' 30"

cot 42° 22' 20"

23. b. $\cos 29^\circ\ 20'\ 10'' = 0.871760$

$\cos 74^\circ\ 15'\ 15'' = 0.271370$

$\cot 89^\circ\ 15'\ 30'' = 0.012945$

$\cot 42^\circ\ 22'\ 20'' = 1.096207$

24. SELF TEST

Find the value of the following functions:

a. sin 36° 15' 00"

b. cos 38° 22' 00"

c. tan 47° 28' 00"

d. cot 54° 36' 00"

e. sin 28° 45' 10"

f. tan 75° 29' 15"

g. cos 52° 38' 20"

h. cot 10° 10' 10"

24. SELF TEST

a. sin 36° 15' 00" = 0.591310

b. cos 38° 22' 00" = 0.784055

c. tan 47° 28' 00" = 1.090035

d. cot 54° 36' 00" = 0.710663

e. sin 28° 45' 10" = 0.481031

f. tan 75° 29' 15" = 3.86324

g. cos 52° 38' 20" = 0.606837

h. cot 10° 10' 10" = 5.57483

25. We learned earlier that the ratio of the ____________ side to the __________ is called the sine of the angle.

25. opposite - hypothenuse

26. We also learned that the ratio of the opposite side to the adjacent side is called the ____________ of the angle and that the ratio of the adjacent side to the hypothenuse is called the ______________ of the angle.

26. tangent, cosine

27. In computing for the function of an angle we arrive at the arithmetical value for that function. It now becomes necessary to convert this value to the size of the angle.

We may end up by arriving at 0.244461 as the value for the sine of angle A. We now enter our tables of Natural Trigonometric Functions and under the sine column look for 0.244461 and find the angle that corresponds to this value to be ______________.

27. 14° 09' 00"

28. What angle is determined if its:

a. sine = 0.344752

b. cos = 0.868920

c. tan = 0.854081

d. cot = 0.988432

28. a. 20° 10'

b. 29° 40'

c. 40° 30'

d. 45° 20'

29. If the sine of angle A is 0.876312, the angle A is __________.

29. We look for 0.876312 and find 0.876307, the next lower number. So our angle is greater than 61° 12' but less than 61° 13'.

The sine of 61° 12' = 0.876307

our sine = 0.876312

or 5 more

In the difference column we find a difference of 2.33 per second. So $\frac{5}{2.33}$ = 2" for the 5 difference. Our angle then has to be 61° 12' + 2" or 61° 12' 02".

30. Given $\cos A = 0.480380$,

find A = ____________.

30. Looking for 0.480380 in the cos column, we find 0.480479 as the value next above our value. (Remember the cosine decreases as the angle increases.)

The angle which goes with 0.480 479 is 61° 17'. The difference between the values of the functions of angle A and 61° 17' is 0.480479 - 0.480380 = 99.

$\frac{99}{4.27}$ = 23.2". So, our angle is 61° 17' 23".

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31. Find angle A if its

a. sine = 0.870394

b. cos = 0.743648

c. tan = 1.821362

d. cot = 1.393268

299

31. a. 60° 30' 16"

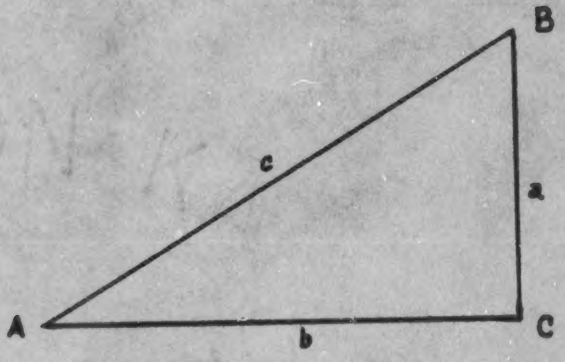
b. 41° 57' 25"

c. 61° 13' 53"

d. 35° 40' 06"

32. Now let us put together all we learned and start to compute some right triangles: Given right triangle ABC with A = 33° 50' and a = 311, solve the triangle.

32.



$A = 38^\circ\ 50'$

$a = 311$

$B = 90^\circ - A = 90^\circ - 38^\circ\ 50' = \underline{51^\circ\ 10'}$

$\sin A = \frac{a}{c}$ therefore $c = \frac{a}{\sin A}$

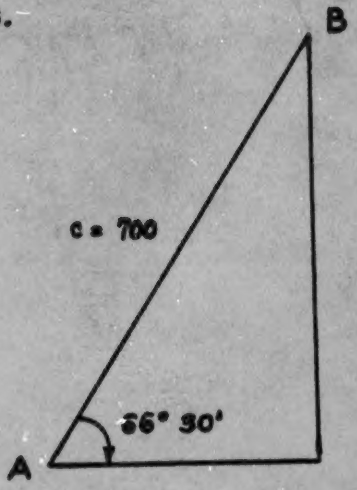
$\tan A = \frac{a}{b}$ therefore $b = \frac{a}{\tan A}$

$c = 311 \div 0.622515 = 499.59$

$b = \frac{311}{0.804979} = 386.34$

33. Solve the right triangle ABC in which A = 66° 30′ and c = 700.

33.



Given: $A = 66^\circ\ 30'$

$c = 700$

Find: B, a, and b.

$B = 90^\circ - A = 90^\circ - 66\ 30' = \underline{23^\circ\ 30'}$

$\sin A = \frac{a}{c}$ therefore $a = c \text{ Sin } A$

$\cos A = \frac{b}{c}$ therefore $b = c \cos A$

$a = 700 \times 0.917060 = 641.94$

$b = 700 \times 0.398749 = 279.12$

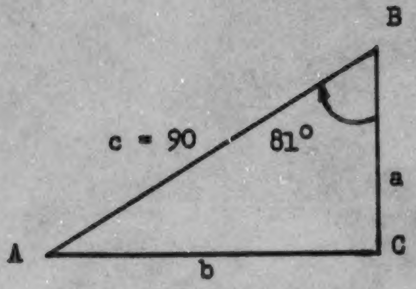
$B = 23^\circ\ 30'$ ans.

$a = 641.94$ ans.

$b = 279.12$ ans.

34. Given B = 81°, c = 90, solve the right triangle.

34.



Given: B = 81°, c = 90

Find: A, a, and b.

$A = 90^\circ - B = 9^\circ$

$\sin B = \frac{b}{c}$, therefore $b = c \sin B$

$\cos B = \frac{a}{c}$, therefore $a = c \cos B$

$b = 90 \times 0.987688 = 88.89$

$a = 90 \times 0.156434 = 14.08$

$A = 9^\circ$ ans.

$b = 88.89$ ans.

$a = 14.08$ ans.

35. Given a = 3872, c = 4105, solve the right triangle.

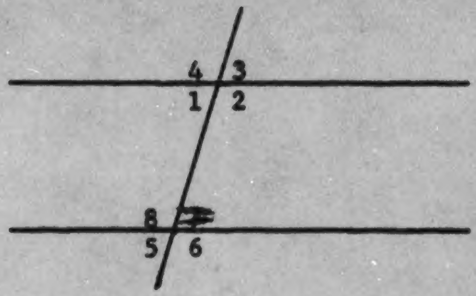
35. A = 70° 36' 10" b = 1363.33

B = 19° 23' 50"

C = 90°

36. In Geometry we learned that: "when parallel lines are cut by a transversal, the alternating interior angles are equal."

Thus:



Angle 1 = Angle ____________

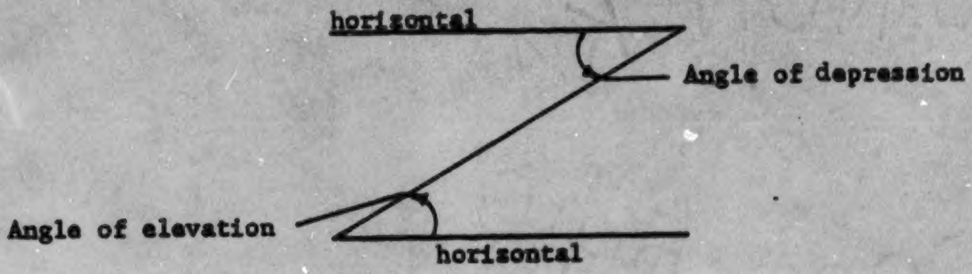
Angle 8 = Angle ____________

(Also angle 1 = angle 3; angle 2 = angle 4; angle 5 = angle 7; and angle 6 = angle 8).

36. 7;2

37. We say that an angle of elevation is measured from the horizontal up and an angle of depression from the horizontal down.

This would give us a sketch similar to this:


horizontal
Angle of depression
Angle of elevation
horizontal

From what we have learned in the preceding panel we can state that:

Angles of elevation = angles of ______________,

and angles of depression = angles of ______________.

37. depression

elevation

38. If a calculator is available, computing by use of Natural Functions is comparatively easy. To use a relatively simple method of computing when no calculator is available we shall use logarithms.

You have had computations by use of logarithms in other lessons. You must get acquainted with the use of logarithms of functions.

Logarithms of Functions are merely the logarithms of the different numerical functions of angles.

To establish this fact, list the following:

the sine (natural) of 30° = ____________.

38. 0.5000000

304

39. The logarithm of 0.500000 = ________________.

315

39. 9.6989700 - 10

40. The log sin 30° = ____________________.

40. 9.6989700 - 10

(So we can see that the log of the function is merely the log of the value of the natural function).

41. In a quick review of operations using logs, we can state that
when multiplying we ____________ the logs.
when dividing we ____________ the logs.
when raising the power we ____________ the log by the exponent.
when extracting a root we ____________ the log by the exponent.

41. add

subtract

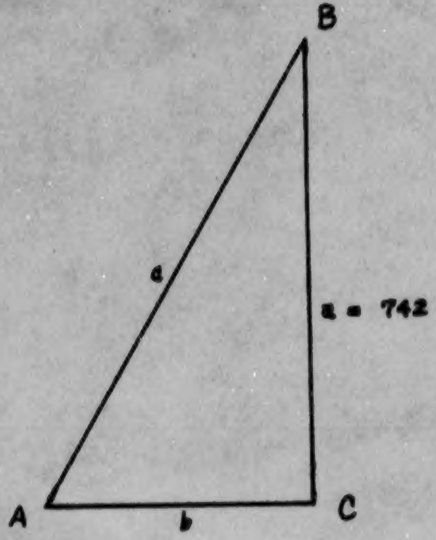
multiply

divide

42. Using logarithms, solve the following right triangle:

Given: A = $65^{\circ} 30'$, a = 742

42.



Given: A = 65° 30'

a = 742

B = 90° - A = 24° 30'

$\sin A = \frac{a}{c}$

$c = \frac{a}{\sin A}$

$\tan A = \frac{a}{b}$

$b = \frac{a}{\tan A}$

log a (742) = 2.870404

- log sin 65° 30' = 0.959023

log c = 2.911381

c = 815.42

log 742 = 2.870404

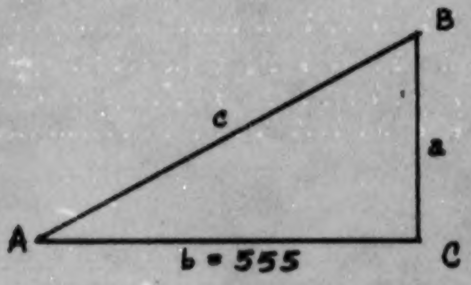
- log tan 65° 30' = 0.341296

log b = 2.529108

b = 338.15

43. Given: $A = 38^\circ 40'$, $b - 555$. Solve the right triangle.

43.



Given: $A = 38^\circ\ 40'$

$b = 555$

Find: B, a, and c.

$B = 90^\circ - 38^\circ\ 40' = 51^\circ\ 20'$

$\cos A = \frac{b}{c}$ therefore $c = \frac{b}{\cos A}$

$\tan A = \frac{a}{b}$ therefore $a = b \tan A$

log 555 = 2.744293

− log cos $38^\circ\ 40'$ = 9.892536

log c = 2.851757

c = 710.82

log 555 = 2.744293

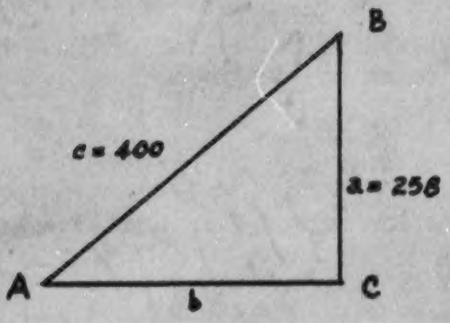
log tan $38^\circ\ 40'$ = 9.903197

log a = 2.647490

a = 444.11

44. In right triangle ABC, given a = 258; c = 400, find A, B, and b.

44.



$\sin A = \frac{a}{c} = \frac{258}{400}$

$\cos A = \frac{b}{c}$ therefore $b = c \cos A$

$B = 90^{\circ} - A$

(Using Vega 7 place Logarithmic Tables)

log 258 = 2.4116197

- log 400 = 2.6020600

log sin A = 9.8095597

A = 40° 9' 56"

log 400 = 2.6020600

+ log cos = 9.8831980

log b = 2.4852580

b = 305.67

FINAL TEST

45. Do the following problems:

a. The angle of elevation of the top of the Los Angeles City Hall from a point on the ground 904 feet from its base is 27° 10'.

How high is the building?

b. The angle of elevation of a ladder leaning against a wall is 77°. The foot of the latter is 1.8 feet from the wall.

How long is the ladder?

c. From a point (A) on top of a cliff that is 160 feet above sea level, the angle of depression to an anchored rowboat (B) is 14° 50'.

Find the length of the line of sight AB.

d. In right triangle ABC, A = 42° 30', and c = 148.75.

Find B, a and b.

e. In right triangle ABC, B = 63° 23' 52" and c = 1001.1.

Find A, a and b.

45. FINAL TEST

a. 463.93 feet

b. 8.0 feet

c. 624.98 feet

d. B = 47° 30'; a = 100.49; b = 109.67

e. A = 26° 36' 08"; a = 448.29; b = 895.12

STUDENT HANDOUT

LESSON: Glossary of Mapping, Charting and Geodetic Technical Terms

OBJECTIVE: In a classroom simulating a cartographic work area, the student will be able to define the mapping, charting and geodetic technical terms that he will encounter in the map making process in accordance with the DOD Glossary of Mapping, Charting and Geodetic Terms.

LESSON OUTLINE:

1. Define Technical Terms.

STUDENT NOTE:

SUMMARY: During this lesson, you have been introduced to the Glossary of Mapping, Charting and Geodetic Technical Terms. This Annex will be a valuable aid to you in order to perform your duties as a map compiler or cartographic draftsman.

GLOSSARY OF MAPPING, CHARTING AND GEODETIC TECHNICAL TERMS

ABSOLUTE ORIENTATION	See Orientation.
ACCURACY	Degree of conformity with a standard. Accuracy relates to the quality of a result, and is distinguished from precision which relates to the quality of refinement of the operation by which the result is obtained.
AERONAUTICAL CHART	A map essentially designed for the aviator, showing obstructions, aids to navigation, and other information to assist the aviator in navigation.
AIR BASE	The line joining two air stations. (Also see Air station; Camera station)
AIR STATION	The camera station for an aerial photograph.
ALTIMETER	An instrument which utilizes relative pressure of the atmosphere to indicate the vertical distance above a specified datum plane.
ALTITUDE	Vertical distance above the datum, usually mean sea level, to an object or point in space.
ANAGLYPH	A picture printed, or projected in complementary colours and combining the two images of a stereoscopic pair, and which gives a stereoscopic image when viewed through spectacles having filters of corresponding complementary colours. The same effect can be obtained by using polarized light and filters.
ANGLE OF COVERAGE	The maximum angle subtended at a lens by light rays forming the image.
APPARENT HORIZON	See Horizon.

AUXILIARY CONTOURS	Additional contours, usually shown by broken lines, interpolated between the contours normally shown. They are usually shown to indicate significant topographic formations which could not be shown by the basic contour interval.
AZIMUTH	The angle, measured clockwise, in a plane tangent either to the spheroid or to the geoid, between a meridian and a point projected onto the plane.
AZIMUTH LINE	A radial line from the principal point, isocenter, or nadir point of a photograph, representing the direction to a similar point on an adjacent photograph in the same line of flight, used extensively in radial triangulation.
AZIMUTHAL EQUIDISTANT PROJECTION	An azimuthal map projection on which straight lines radiating from the center or pole of projection represent great circles in their true azimuths from that center, and lengths along those lines are of exact scale. This projection is neither equal-area nor conformal.
BAR SCALE	A line or system of parallel lines divided at specified intervals to indicate distances on the map. It is customarily a part of the marginal information.
BAROMETER	An instrument for measuring the pressure of the atmosphere.
ANEROID BAROMETER	A thin, hollow, corrugated metal box which changes form with changes of air pressure, thereby affording a means of measuring atmospheric pressure.

BASE LINE	The line on the photograph connecting the indicated positions of two camera stations. When applied to the multiplex, the line connecting the lens nodes of adjacent multiplex projectors. Corresponds to and is a miniature representation of the air base.
BATTLE MAP	See Map.
BENCH MARK	An accurately established elevation point of third order accuracy or better, defined on the map by a black sawbuck cross. A monumented bench mark is one marked by a tablet. The symbol is labeled "BM" A nonmonumented bench mark is one marked, but not by a tablet. (See also Control.)
BINOCULAR VISION	Simultaneous vision with both eyes.
BLUELINE	An image obtained by coating a surface with a light-sensitive iron salt which decomposes when exposed to a brilliant light. Exposed areas turn blue when developed. The blueline is nonphotographic under controlled photographic processes.
BLUELINE BOARD	An image processed in nonphotographic blue on a high quality drafting surface which has previously been mounted on a rigid (stable) material.
BORDER INFORMATION	See Marginal data.
BRIDGING	The extension and adjustment of photogrammetric surveys between bands of ground control.
BURNISH	To polish by friction with an instrument of bone, glass or steel.
C FACTOR	The ratio of flight altitude to contour interval which may be compiled with 90 percent of elevations interpolated from the contours accurate to within one-half the contour interval.

CALIBRATION	The act or process of determing certain specific measurements in a camera, or other instrument, for comparison with a standard.
CAMERA	A chamber or box within which the images of exterior objects are projected and recorded on a sensitized surface.
CAMERA STATION	The point in space, in the air or on the ground, occupied by the camera lens at the moment of exposure.
CANTILEVER EXTENSION	The extension of a strip of photographs by photogrammetrical methods from a controlled area to an area with no control. (See also Multiplex triangulation; Radial triangulation)
CARTOGRAPHY	The science or art of expressing graphically, by means of maps and charts, the known physical features of the earth's surface and the works of man and his varied activities.
CENTRAL MERIDIAN	The line of longitude occupying the center of a projection. Generally the basis for constructing the projection.
CLASSIFICATION SURVEY	The process of comparing aerial photographs with conditions as they exist on the ground and of obtaining information to supplement or clarify that which is not readily discernible on the photographs themselves.
COLOR SEPARATION	Separation or isolation of the several colours of an original copy into individual images. Scribed plastic sheets prepared individually for specific colours become separation negatives. Photographs of these blueline boards produce colour separation negatives.

COMPILATION	The process of extracting map detail from aerial photographs and/or other sources, to fit a control network in the preperation of a map.
COMPOSITE PRINT	Reproduction from a successive series of images. A proof made by exposing the negatives of color-seperation boards one after the other on a single sheet of black and white or blueprint photo paper which when developed "composes" or contains the images of all the negatives on a single sheet. Used in checking and editing.
CONTOUR.	An imaginary line connecting the points on a land surface that have the same elevation; also the line representing this on a map.
CONTOUR INTERVAL	The constant difference in elevation between successive contours.
CONTOUR MAP	See Map
CONTROL	A system of relatively accurate measurements to determine the distances and directions or differences in elevation between points on the earth, upon which depends a system of lesser accuracy.
ASTRONOMIC CONTROL	Control established by observation upon heavenly bodies.
GEODETIC CONTROL	Control which takes into account the size and shape of the earth; i.e. system of points of known latitude longitude and elevation.
GROUND CONTROL	Control obtained by ground surveys as distinguished from control obtained by photogrammetric methods.
HORIZONTAL CONTROL	Control which determines horizontal positions only, as with respect to parallels and meridians or to other lines of reference.

MULTIPLEX CONTROL	Control established from other existing control by bridging or by cantilever extensions with the multiplex projectors.
RECOVERED CONTROL	Control previously established from other sources, which can be identified.
VERTICAL CONTROL	Control which determines position with respect to elevations only.
CONTROL POINT	Any station in a horizontal and/or vertical control system that is identified on a photograph and used for correlating the data shown on it.
CONTROLLED MOSAIC	See Mosaic.
COORDINATES	Linear or angular quantities (usually two-dimensional) which designate the position which a point occupies in a given reference plane or system.
GRID COORDINATES	A plane rectangular coordinate system based upon, and mathematically adjusted to a map projection in order that geographic positions (latitudes and longitudes) readily may be transformed into plane coordinates and the computations relating to them by the ordinary methods of plane surveying.
PLANE COORDINATES	A system of coordinates in a horizontal plane, used to describe the positions of points with respect to an arbitrary origin by means of two distances perpendicular to each other.
RETANGULAR COORDINATES	Same as plane coordinates, sometimes called plane rectangular coordinates.
CRAB	Angle between the edge of a photograph not being parallel to the line of flight.

CULTURE	Those features of terrain that have been constructed by man, such as roads, trails, buildings, and canals; also boundary lines and all names and legends.
DATUM	A referenced element, such as a line or plane, in relation to which the positions of other elements are determined.
DIP ANGLE	The angle between the apparent horizon and the true horizon.
DIRECTION OF TILT	The direction (azimuth) of the principal plane of a photograph.
DOMESTIC MAP	A map of an area within the limits of the United States.
EDITING	The process of checking a map in its various stages of preparation to insure correct preparation from and interpretation of the sources used, and assure legible and precise reproduction.
ELEVATION	Vertical distances above the datum, usually mean sea level, to a point or object on the earth's surface.
EQUATOR	An imaginary line around the earth which is everywhere equidistant from the poles.
FIDUCIAL MARKS	Index marks rigidly connected with the camera lens through the camera body and forming images on the negative which define the principal point of the photograph.
FILM NEGATIVE	A negative made on film, as contrasted to a glass negative. (See also negative.)
FILM POSITIVE	A film on which the image of the original object corresponds to the same in the scheme of light and shade.

FILTER	Any transparent material which absorbs a certain portion of the spectrum.
FIREBREAK	A strip through woodlands from which trees and underbrush have been cut to impede the progress of forest fires.
FLIGHT ALTITUDE	The vertical distance above a given datum of an aircraft in flight, or during a specified portion of a flight. The datum usually is mean ground elevation.
FLIGHT LINE	A line drawn on a map or chart to represent the track over which an aircraft has been flown, or the course over which it is to be flown.
FLIGHT MAP	See Map.
FLOATING MARK	A mark seen as occupying a position in the three-dimensional space formed by the stereoscopic fusion of a pair of photographs, and used as a reference mark in examining or measuring the stereoscopic model.
FOCAL LENGTH	Perpendicular distance between the image plane and the rear node of the lens when the lens is set to project light rays from infinity.
FOCAL PLANE	The plane perpendicular to the axis of the lens in which images of points in the object field of the lens are focused.
FORESHORE	That area which is bare or awash at low tide, but covered at high tide.
FORM LINES	Lines having the same appearance as contour lines but which have been sketched from visual observation to show the shape of the terrain rather that its elevation.

FORWARD LAP	See Overlap.
FOUL GROUND	Any area which is shoal, but covered at low tide.
GAZETTEER	A list of place names usually giving the geographic locations and grid references of the places listed.
GEODETIC CONTROL	See Control.
GREAT CIRCLE	The largest circle that can be drawn through any given point on the globe.
GREENWICH MERIDIAN	The meridian passing through Greenwich, England, and designated as the zero or standard meridian on maps made in Britain, the United States, and many other countries.
GRID REFERENCE BOX	A box appearing in the map's margin containing instructions for determining grid references.
GRID SYSTEM	(1) A systematic network of lines on a plane surface upon which coordinates are based and to which the map features are referenced. (2) A rectangular network of lines on a map projection.
GRID COORDINATES	See Coordinates.
GRID VALUES	Numbers appearing in the margin of and on the face of a map labeling grid lines.
GRID ZONE	A column, 6° in latitude, whose grid coordinates are based on the same origin. In the Universal Transverse Mercator Grid System, the zones are numbered from 1 to 60°, beginning at 180 and progressing eastward.
GROUND CONTROL	See Control.
GROUND SURVEY	See Survey.

HIGH OBLIQUE PHOTOGRAPH	An oblique photograph which shows the horizon.
HORIZON	
APPARENT HORIZON	The apparent or visible junction of earth and sky as seen from any specific position. Also called visible horizon.
TRUE HORIZON	A horizontal plane passing through a point of vision or perspective center.
HORIZON TRACE	An imaginary line on the plane of the photograph which represents the image of the true horizon.
HORIZONTAL CONTROL	See Control.
HORIZONTAL CONTROL POINT	A control point in a horizontal control system. (See also Control point.)
HYDROGRAPHIC CHART	A chart showing water depths, islands, channels, the conformation of the sea or lake bottom, and aids and menaces to navigation. It also shows the typography of the shore and as much of the land's salient features as would serve the navigator as landmarks.
HYDROGRAPHIC DATUM	The plane of reference of soundings, depth curves and elevations of foreshore and off shore features.
HYDROGRAPHY	The plotting on a hydrographic map of the topography of the shores and banks, the depths of soundings and other desireable detail.
HYPSOGRAPHY	Parts of a map, such as contours and contour values, which represent relief.
ISOCENTER	The point on a photograph intersected by the bisector of the angle between the plumb line and the photograph perpendicular.

LOW-OBLIQUE PHOTOGRAPH	An oblique photograph with the entire picture below the horizon.
LOXODROME	See Rhumb line.
MANUSCRIPT MAP	The original drawing of a map as compiled or constructed by multiplex topographers or map compilers from various data such as ground surveys and photographs.
MAP	A graphical representation, usually on a plane surface and at an established scale, of natural and artificial features on the surface of a part or the whole of the earth or othe planetary body. The features are positioned as accurately as possible, usually relative to a coordinate reference system.
AERONAUTICAL MAP	See aeronautical chart.
BATTLE MAP	A map suitable for the tactical and technical needs of a commander.
CONTOUR MAP	A topographic map which portrays relief by means of contour lines.
FLIGHT MAP	A map on which are indicated the desired lines of flight for a photographic mission.
ORTHOPHOTOMAP	A photomap made from an assembly of orthophotographs. (See also orthophoto.)
PHOTOMAP	The reproduction of a single photograph, composite, or mosaic complete with grid lines and marginal data.
PLANIMETRIC MAP	A map which presents only the horizontal positions for the features represented; distinguished from a topographic map by the omission of relief in measurable form.
RECONNAISSANCE MAP	A map prepared from reconnaissance survey. (See also Reconnaissance)

STRATEGIC MAP	A topographic or planimetric map used for planning operations, including movements, concentrations, and supply of troops.
TACTICAL MAP	A topographic map for general field use and tactical and logistic studies by units from corps and higher.
TOPOGRAPHIC MAP	A map which presents the horizontal and vertical positions of the features represented; distinguished from a planimetric map by the addition of relief in measurable form.
MAP PLANE	Any horizontal plane to which the planimetry and relief of an area are plotted or referenced.
MAP PROJECTION	See Projection.
MARGINAL DATA	Information in the margin of maps which is of aid in filing the maps, in interpreting them, and in determining their accuracy, as well as for general information.
MECHANICAL ARM TEMPLET	See Templet
MODEL	See Stereoscopic model.
MOSAIC	An assembly of two or more overlapping aerial photographs. Also called aerial mosaic.
CONTROLLED MOSAIC	A mosaic fitted to a control plot by rephotographing the component vertical photographs to compensate for scale variations resulting from tilt and for variations in flight altitude.
UNCONTROLLED MOSAIC	An assembly of two or more overlapping vertical photographs assembled only by matching photographic detail without the benefit of a framework of control points.

STRIP MOSAIC	An assembly of a strip of vertical photographs taken in a single flight.
MOSAIC INDEX	A small scale reproduction of a mosaic which serves as a guide to the individual photographs which may be used for planning mapping projects.
MULTIPLEX	A stereoscopic plotting instrument used in preparing topographic maps by stereophotogrammetry.
MULTIPLEX CONTROL	See Control.
MULTIPLEX EXTENSION	The extension of a strip of photographs by stereophotogrammetric methods. (See also Cantilever extension; Multiplex triangulation.)
MULTIPLEX MODEL	An optical projection of two overlapping images in complementary colours by means of the multiplex projectors, which gives a stereoscopic image when viewed through spectacles having filters of corresponding complementary colours.
MULTIPLEX PROJECTOR	An instrument which forms a part of the multiplex equipment and which projects a reduced copy of the aerial negative.
MULTIPLEX TRACING TABLE	A piece of multiplex equipment used for viewing the stereoscopic model measuring the elevations in it, and compiling the detail on a map plane.
MULTIPLEX TRIANGULATION	See Triangulation.
NADIR	That point on a celestial sphere directly beneath the observer and directly opposite to the zenith. Photograph nadir (or nadir point) That point at which a vertical line through the perspective center of the camera lens pierces the plane of the photograph.

NEATLINE	The line which surrounds the map itself. The margin is outside the neatline.
NEGATIVE	A sensitized plate or film which has been exposed in a camera and which has the lights and shades in inverse order to those of the original subject.
OBLIQUE PHOTOGRAPH	A photograph taken with the camera axis directed intentionally between the horizontal and the vertical.
HIGH OBLIQUE	An oblique photograph in which the apparent horizon is shown.
LOW OBLIQUE	An oblique photograph in which the apparent horizon is not shown.
ORIENTATION:	
RELATIVE ORIENTATION	(1) The reconstruction of the same perspective conditions between a pair of photographs which existed when the photographs were taken. (2) The orientation of one multiplex projector with reference to another to produce the relative relationships of the taking camera.
ABSOLUTE ORIENTATION	The fixation of scale, position, and orientation of the stereoscopic model produced by relative orientation with reference to the ground coordinates. A multiplex model with correct scale and horizontalization is an absolute orientation.
ORTHOGRAPHIC PROJECTION	See Projection.
ORTHOPHOTOGRAPH	A photographic copy, prepared from a perspective photograph, in which the displacements of images due to tilt and relief have been removed.

OVERLAP	Amount by which one photograph overlaps the area covered by another, customarily expressed as a percentage.
FORWARD LAP	The overlap between two photographs in the same flight.
SIDE LAP	The overlap between photographs in adjacent parallel flights.
OVERLAPPING PAIR	Two photographs taken at different exposure stations in such manner that a portion of one photograph shows the same terrain shown on a portion of the other photograph.
OVERLAY	A record on a transparent medium to be superimposed on another record.
PANELING NEGATIVES	Cutting a film negative in which some distortion is involved, into several pieced and cementing them in place, on a projection drawn on vinylite, in such a way that the error is distributed in small amounts throughout the area rather than being localized.
PARALLAX	The apparent displacement of the position of a body with respect to a reference point or system, caused by a shift in the point of observation.
ABSOLUTE PARALLAX	Considering a pair of truly vertical photographs, of equal principal distances, taken from equal flight altitudes; or a pair of rectified photographs; or a stereoscopic model formed by the multiplex projectors of such photographs; The absolute parallax of a point is the algebraic difference, parallel to the base line, of the distances of the two images from their respective principal points. It is a measure to scale of the height of the image in space.

X PARALLAX OR HORIZONTAL PARALLAX	Synonymous with absolute parallax and also used in multiplex operations to denote the component of distances between the corresponding images of a point in a stereoscopic model in a direction parallel to the vertical plane containing the base line when that model is intercepted by a horizontal plane, such as the platen of the multiplex tracing table.
Y PARALLAX OR VERTICAL PARALLAX	The difference of the perpendicular distances of the two corresponding images of a point in overlapping photographs or projections of photographs from the vertical plane containing the base line.
PASS POINT	A point the horizontal and/or vertical position of which is determined from photographs by photogrammetric methods, and which is intended for use after the manner of a ground-control point in the orientation of other photographs.
PERSPECTIVES	The two-dimensional appearance of the object with reference to the point of observation.
PERSPECTIVE CENTER	The point of origin or termination of bundles of perspective rays; in photography, the rear node of the lens is the perspective center of the photograph, and the front node of the lens is the perspective center of the object.
PERSPECTIVE GRID	A network of lines drawn or superimposed on a photograph, which represents the perspective of a systematic network of lines on the ground or datum plane.
PERSPECTIVE PROJECTION	See Projection.

PHOTOGRAMMETRY	The science and art of obtaining reliable measurements from photographs.
PHOTOGRAPH	A general term for a positive or negative picture made by a camera on plate, film or other medium.
PHOTOGRAPH PERPENDICULAR	The perpendicular from the interior perspective center - rear node of lens - to the plane of the photograph.
PHOTOMAP	See Map.
PLANE COORDINATES	See Coordinates.
PLANIMETRY	Part of a map which represent everything except relief; that is, works of man, and natural features such as woods and water.
PLANIMETRIC MAP	See Map.
PLOTTING SCALE	The scale at which a map is to be compiled. The scale of the multiplex model in absolute orientation.
PLUMB POINT	The point on the ground vertically beneath the perspective center of the camera lens.
POSITIVE	A photograph having the same approximate rendition of light and shade as the original subject.
PRESS PROOF	A lithographed map taken from among the first copies run on the press and used for editing purposes.
PRINCIPAL DISTANCE	The perpendicular distance from the interior perspective center to the plane of a particular finished negative or print. Distance from the rear node of the lens to the principal point of a photograph.
PRINCIPAL LINE	The trace of the principal plane upon the photograph. (See also Principal plane.)

PRINCIPAL PLANE	The vertical plane through the internal perspective center containing the photograph perpendicular of an oblique photograph; that is, any photograph which is not a truly vertical photograph.
PRINCIPAL POINT	The foot of the perpendicular from the interior perspective center to the plane of the photograph; that is, the foot of the photograph perpendicular.
PRINT	A photographic copy made by projection or contact printing from a photographic negative or from a transparent drawing, as in blueprinting.
CONTACT PRINT	A print made with the negative or transparent drawing in contact with the sensitized surface.
RATIO PRINT	A print the scale of which has been changed from that of the negative by photographic enlargement, reduction, or restitution.
PROJECTION	(1) In geometry, the extension of lines or planes to intersect a given surface. (2) The transfer of a point from one surface to a corresponding position on another surface by graphical or analytical methods.
MAP PROJECTION	(1) A systematic drawing of lines on a plane surface to represent the parallels of latitude and the meridians of longitude of the earth or a section of the earth. (2) A geometric projection on a plane surface.
PERSPECTIVE PROJECTION	The projection of points by straight lines drawn through them from some given point to an intersection with the plane of projection.

ORTHOGRAPHIC PROJECTION	A perspective projection of points by straight lines from a point of projection at an infinite distance from the plane of the drawing.
PROJECTION DISTANCE	In the multiplex projector, the distance from the front node of the projector lens to the plane of projection.
RADIAL	A line or direction from the radial center to any point on a photograph. The radial center for truly vertical photographs is the principal point.
RADIAL TRIANGULATION	See Triangulation.
RATIO PRINT	See Print.
RECONNAISSANCE	A general examination or survey of a region with reference to its main features, usually as a preliminary to a more detailed survey.
RECTANGULAR COORDINATES	See Coordinates.
RECTIFICATION	The process of projecting a tilted or oblique photograph to a horizontal reference plane, the angular relation between the photograph and the plane being determined from known or estimated data.
RECTIFIED PHOTOGRAPH	A photographic print made by projection in a rectifying printer which has been properly set for rectification.
RELATIVE ORIENTATION	See Orientation.
RELIEF	The variation in the height of the earth's surface. The third dimension in depth perception.
RELIEF MODEL	A general category which denotes any three dimensional representation of an object or geographic area, modeled in any size or medium. Subordinate categories - not interchangeable with the general term are:

TERRAIN MODEL	Any three dimensional model of a geographic area constructed to scale. A specific and distinct type of the terrain model is the plastic relief map; however, through extended use, it has become classified as a separate product.
PLASTIC RELIEF MAP	A topographic map printed on plastic and molded into a three dimensional form. The plastic medium is generally formed by heat and vacuum over a terrain model to achieve the three dimensional representation.
REPRODUCTION	The summation of all the processes involved in printing copies from an original drawing.
RHUMB LINE	A line which crosses successive meridians at a constant angle, also loxodrome. The Mercator is the only projection on which a rhumb line is represented by a straight line.
SCALE	The ratio of distance measured on a map to the corresponding distance on the ground. Different from representative fraction only in that scale can be expressed in other than fractional form; that is, such as an equation with different units of measurement on each side.
SCALING	(1) Alteration of the scale in photogrammetric triangulation to bring the model into agreement with a plot of horizontal control. (2) Fitting a stereoscopic model to a horizontal control plot. A step in absolute orientation.
SEPIA PRINT	A photographic reproduction obtained by the use of a surface with a light sensitive iron and silver salt in a gelatin coating, which after exposure to brilliant light will turn brown when developed.

SIDE LAP	See Overlap.
SLOTTED TEMPLET	See Templet.
SPATIAL MODEL	A stereoscopic model. (See also stereoscopic model.)
SPHERE	A body of space bounded by one surface, all points of which are equally distant from a point within called its center.
STANDARD	An exact value, or concept thereof, established by authority, custom, or common consent, to serve as a rule in the measurement of quantity, or in the establishment of a practice or procedure.
STEREOSCOPY	The science and art which deal with stereoscopic effects and the methods by which they are reproduced.
STEREOSCOPIC FUSION	That mental process which combines two perspective images of an object on the retinas of the eyes to give a mental impression of a three dimensional model.
STEREOSCOPIC IMAGE OR STEREOSCOPIC MODEL	That mental impression of a three dimensional model which results from stereoscopic fusion of a stereoscopic pair.
STEREOSCOPIC PAIR	Two photographs of the same area taken from different camera stations in such a manner as to affort stereoscopic vision. Also called a stereogram.
STEREOSCOPIC VISION	That particular application of binocular vision which enables the observer to view an object, or two different perspectiv es of an object - as two photographs of the same images taken from different camera stations - and to obtain therefrom the mental impression of a three dimensional model.

STEREOGRAM	See Stereoscopic pair.
STEREOSCOPE	An optical instrument for assisting the observer in obtaining stereoscopic vision from two properly prepared photographs.
STICK-UP	A gum-backed opaque or wax-backed transparent material, on which names, numbers, or symbols are printed for the purpose of imposing them on the drafted copy, thereby eliminating the necessity of hand drafting.
STIC-PAT	An adhesive-backed cellophane on which map symbols are printed.
STRATEGIC MAP	See Map.
SURVEY	The act or operation of making measurements for determining the relative position of points on or beneath the earth's surface.
AERIAL SURVEY	(1) A survey utilizing aerial photographs as part of the surveying operations. (2) The taking of aerial photographs for surveying purposes.
TACTICAL MAP	See Map.
TEMPLET	A substitute for a photograph used in radial triangulation, on which is recorded the radial center and the radial lines taken from the photograph.
SLOTTED TEMPLET	A mechanical templet on which the radial are represented by slots cut in a sheet of cardboard, metal, or other material.
MECHANICAL-ARM TEMPLET OR SLOTTED-ARM TEMPLET	A templet which is formed by attaching slotted steel arms, which represent the radials to a center core.
TERRAIN	An area of ground considered as to its extent and topography.

TILT	The angle between the photograph perpendicular and a vertical through the air station.
TIP AND TILT	In practical photogrammetry, the X and Y components of absolute tilt are referred to as tilt and tip, respectively; that is, tip is the rotation of a photograph about the Y-axis or the axis perpendicular to the line of flight, and tilt is that about the X-axis or the axis parallel to the line of flight.
TOPOGRAPHY	The features of the actual surface of the earth considered collectively as to form.
TOPOGRAPHIC MAP	See Map.
TRAVERSE	A method of surveying whereby the lengths and directions of lines connecting a series of stations are measured.
TRIANGULATION	
AERIAL TRIANGULATION	The determination of relative or absolute positions of different points on the earths surface by utilizing aerial photography.
MULTIPLEX TRIANGULATION	A stereophotogrammetric method of aerial triangulation utilizing successive stereoscopic images from overlapping aerial photographs in the multiplex projectors for the location of points, imaged on the photographs, in their correct relative position to one another.
RADIAL TRIANGULATION	A photogrammetric method of aerial triangulation, either analytic or graphic, utilizing overlapping vertical, nearly vertical, or oblique aerial photographs for the location of points, imaged on the photographs, in their correct relative position to one another.

TRUE HORIZON	See Horizon.
UNCONTROLLED MOSAIC	See Mosaic.
VERTICAL CONTROL	See Control.
VERTICAL CONTROL POINT	A control point in a vertical control system. (See also Control point.)
VERTICAL PARALLAX	See parallax.
VERTICAL PHOTOGRAPH	An aerial photograph made with the camera axis vertical or as nearly vertical as practicable.
VINYLITE	A synthetic resin or plastic material, from .005 inch to 1/8 inch thick in increments of .0025 inch. It differs completely from acetate both in composition and the method used to produce it.
ZIP-A-TONE	Adhesive-backed cellophane on which symbols for maps are printed. Zip-a-tone may be cut in any desired size or shape and applied to drawings. (See also Stic-Pat.)

PROGRAMMED LESSONS

Cartographic Drafting

[illegible]

[illegible]

[illegible]

[illegible]

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

MAP MARGINAL INFORMATION

PROGRAMED INSTRUCTION

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INTRODUCTION

This self-teaching text concerning the marginal information of military maps covers those skills needed by everyone who uses military maps and map substitutes. It provides a foundation for personnel whose training program will require specialized or more advanced skills.

LESSON OBJECTIVES

Upon completion of this programed lesson, you will be able to:

a. Identify the marginal information pertinent to a map sheet.

b. Interpret the numerical system used on maps, such as, sheet number, series numbers, stock number, etc.

INSTRUCTIONS TO STUDENTS

This text consists of FRAMES and PANELS. A FRAME presents a single teaching point which usually requires an answer to a specific problem. A PANEL is an illustration or other information needed to solve the problem in the frames.

The problem in some frames requires you to write an answer. In others you select a correct choice and draw a circle around it. A few frames are called INFORMATION or REVIEW frames and do not need an answer. When a frame refers to a panel find the correct panel (printed after the frames) and study it before answering the question.

Start with Frame 1 in the upper half of the page titled LEVEL A. Continue through the booklet on LEVEL A before returning to the front to start on LEVEL B; work through LEVEL B until you have completed the lesson. The correct answer for each frame is printed in parentheses above the next frame. Example: The answer to Frame 1 will be found in parentheses above Frame 2. If you answer any frame incorrectly, turn back to the original frame and restudy it and change your answer to the correct one.

The last frame directs you to do a practical exercise. This is where you will demonstrate what you have learned in the lesson.

The following materials will be needed to complete the self-test at the end of this lesson: Map of Virginia (Indian Head) 1:50,000.

FRAME #1 **LEVEL A**

Map identifications are those standard items appearing in the margin of maps and serve to identify a map completely and specifically. This text is designed to teach you to identify and interpret the information outside the limits or neatline of the map itself. All features outside the neatline of a map are part of the marginal information.

(No response) **LEVEL B**

FRAME #26

For the series number below, list the designation for each element.

a. V ____________

b. 8 ____ ______

c. 3 ____________

d. 4 ______ ___ ___

e. P* ____________

* Not always used.

(No response)

FRAME #2

Marginal information is necessary to help interpret the map since maps are of different classifications, made using different methods and cover different areas of the world. It is always important to examine the marginal information before using a particular map. The information that appears outside the neatline is an aid to ________________ a map.

(Reginal area - scale - sub-region - series separation - special purpose)

FRAME #27

It is important that we distinguish between the series number and the sheet number.

5561IIINW is the ________________.

V834 is the ________________.

(interpret)

FRAME #3

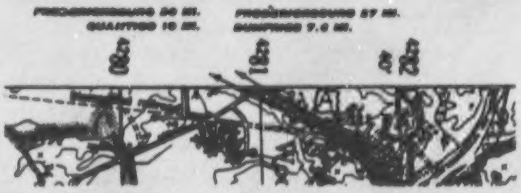
Although maps are used for different purposes, they all generally contain the same marginal information. Because maps are printed by specifications using different style sheets, the information may be placed in various locations around the neatline of the map. Some marginal data may appear in the upper left portion of one map sheet and in the upper right of another. This would depend upon the particular __________ __________ the map specifications are taken from.

Refer to Plate 4 for an example of a typical style sheet.

(Sheet number - series number)

FRAME #28

Another part of the marginal information that is found in the margin of a map are road destinations. A typical road destination is shown below:



These destinations indicate the distance from the neatline of the map to a particular destination along the path indicated. Using the above example and looking at the main road, how far would you travel to Fredericksburg?

(style sheet)

FRAME #4

The first part of the marginal data information of large scale topographic maps we will examine is the sheet name. This is usually the largest populated place shown on this particular sheet, even though this map sheet may be part of a larger complex. The sheet name is usually found in the top center of a map sheet and is usually the _________ _________ _________ of the particular sheet.

(30 miles)

FRAME #29

The Edition Number is also an important part of the map marginal information. An example is shown below:

EDITION 3-TPC

(The coded initials represent the mapping agency responsible for the publication; i.e., TPC - United States Topographic Command.)

The edition number represents the AGE of a map in relation to other editions of the same map. Edition numbers run consecutively and the latest edition will have the largest number. If you needed the most up-to-date map, which one would you select?

EDITION 1-TPC

EDITION 3-TPC

(largest - populated - place)

FRAME #5

Related to the sheet name of a map is the sheet number. The sheet number is used as a reference number. Let's see how this particular number is determined. A particular sheet number for a 1:25,000 scale topographic map would be 5662IINW. The first four numbers 5662 are based upon an arbitrary geographic coordinate system in which each map sheet has a scale of 1:100,000. The first four numbers of a sheet number identify a map of an area that is published at a scale of ______________.

(Edition 3-TPC)

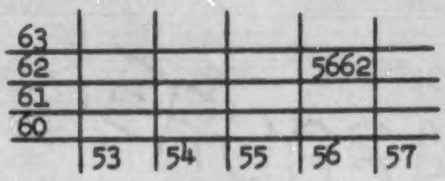
FRAME #30

The symbol legend is another item of marginal data on all topographic maps. It illustrates and identifies the more prominent topographic symbols used on the map. Each symbol is shown in its proper color unless the color does not appear on the interior of the map. A standard legend is tailored to include a symbol in order to avoid repetitive labeling on the map. If you saw a symbol on a map that was unfamiliar you would try to identify it using the ______________ ____________ on the map.

(1:100,000)

FRAME #6

The basic development of the first four numbers of a sheet number for 1:100,000 scale maps is shown below:

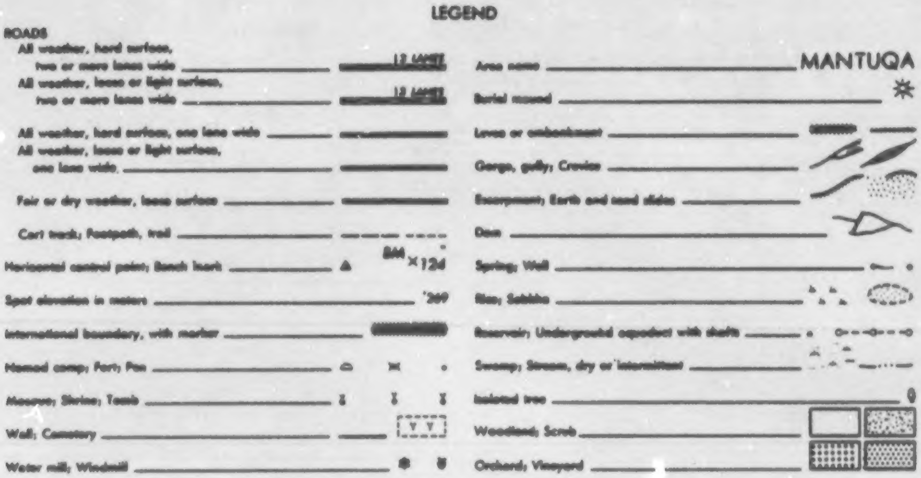

63
62
61
60
5662
53
54
55
56
57

If you had a map sheet that had just four numbers for the sheet number, it would be at a scale of ________________?

(symbol - legend)

FRAME #31

A typical standard symbol legend is shown below (not in color). Using this legend, identify the following symbol ⊥⊥


LEGEND
ROADS
All weather, hard surface, two or more lanes wide
2 LANES
All weather, loose or light surface, two or more lanes wide
2 LANES
All weather, hard surface, one lane wide
All weather, loose or light surface, one lane wide
Fair or dry weather, loose surface
Cart track; Footpath, trail
Horizontal control point; Bench mark
BM ×124
Spot elevation in meters
209
International boundary, with marker
Nomad camp; Fort; Pass
Mosque; Shrine; Tomb
Wall; Cemetery
Water mill; Windmill
Area name
MANTUQA
Burial mound
Levee or embankment
Gorge, gully; Crevice
Escarpment; Earth and sand slides
Dam
Spring; Well
Rim; Sabkha
Reservoir; Underground aqueduct with shafts
Swamp; Stream, dry or intermittent
Isolated tree
Woodland; Scrub
Orchard; Vineyard

(1:100,000)

FRAME #7

So far we have determined only the 1:100,000 scale sheet number. Next, we take the "5662" sheet and divide it into 4 equal parts so that we now have four separate new maps. Each part is labeled in roman numerals as shown below:

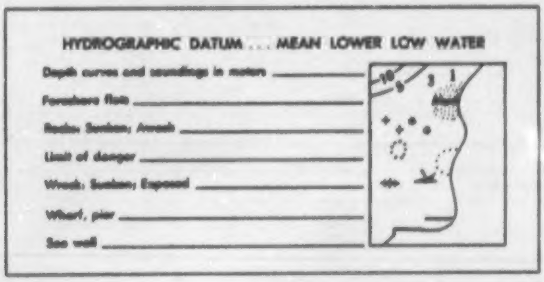
IV	I
III	II

NOTE: The numerals start at the upper right and proceed clockwise to the upper left. After determining what the 1:100,000 scale number is, we divide that area into __________ equal parts.

(rice)

FRAME #32

When a coastal area occurs on a map, a hydrographic legend is shown in the open water area. An example of this type of legend is shown below (not in color):


HYDROGRAPHIC DATUM . . . MEAN LOWER LOW WATER
Depth curves and soundings in meters
Foreshore flats
Rocks: Sunken; Awash
Limit of danger
Wreck: Sunken; Exposed
Wharf, pier
Sea wall
10
5
3
1

(4)

FRAME #8

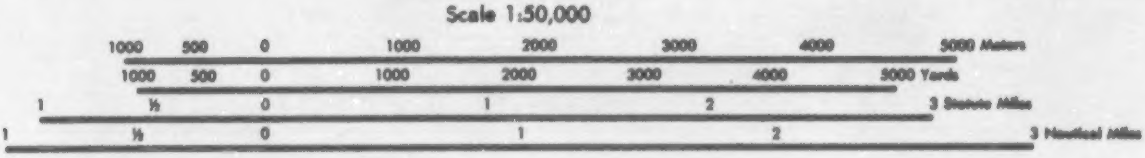
Correctly divide and label the 1:100,000 scale map shown below.

4495

(No response)

FRAME #33

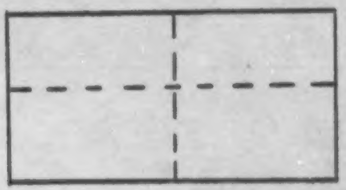
Bar Scales are graphic expressicns of the map scale which provide means of making measurements. A bar scale is used like a ruler to convert a distance measured on a map to a corresponding distance on the ground. In what four units of measurement can we determine a gound distance using the below shown bar scale?


Scale 1:50,000
1000 500 0 1000 2000 3000 4000 5000 Meters
1000 500 0 1000 2000 3000 4000 5000 Yards
1 ½ 0 1 2 3 Statute Miles
1 ½ 0 1 2 3 Nautical Miles

(See FRAME #7)

FRAME #9

The divisions of the 1:100,000 sheet number "5662" into roman numberal parts allows identification of any one of the four parts. Shade in the area of the map sheet whose sheet number is 5662II.



5662

(statute miles - meters - yards - nautical miles)

FRAME #34

The bar scales provide a means for making measurements on a map. These measurements, expressed in any of four units represent the ratio of a distance on the _______________ to a comparative distance on the map.

(Lower right)

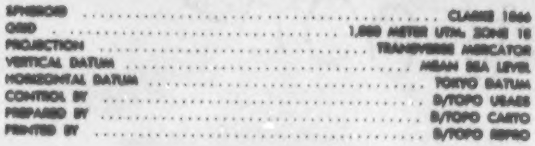
FRAME #10

Each of the four parts of the 1:100,000 scale map determines the boundary of a 1:50,000 map sheet. Thus 5662II is a 1:50,000 map sheet. If you had a map sheet whose number was 4436IV, the scale of that map would be ______________.

(ground)

FRAME #35

Credit for the compilation and printing, as well as the internal factors involved with the making of the map are included in what is known as the Credit Note. Credit notes on recently published maps not only tell who make the map but also what grid and projection were used, what horizontal and vertical datums the map is based upon, where geodetic control was obtained, and who printed the map. Example:

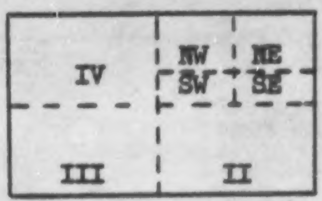


SPHEROID	CLARKE 1866
GRID	1,000 METER UTM. ZONE 18
PROJECTION	TRANSVERSE MERCATOR
VERTICAL DATUM	MEAN SEA LEVEL
HORIZONTAL DATUM	TOKYO DATUM
CONTROL BY	D/TOPO USAES
PREPARED BY	D/TOPO CARTO
PRINTED BY	D/TOPO REPRO

(1:50,000)

FRAME #11

The next step is to break the 1:50,000 map sheet 5662I into four more equal parts. Each breakdown of a 1:50,000 scale map is identified by a compass direction. Using the diagram below, divide 5662III into four parts and label each.



NE - Northeast
SE - Southeast
SW - Southwest
NW - Northwest

(No response)

FRAME #35

Credit notes on older maps are located above the symbol legend and are written in textual form. Example:

> Prepared by the Army Map Service (AMCE), Corps of Engineers, U. S. Army, Washington, D. C. Compiled in 1954 by photogrammetric methods. Horizontal and vertical control by USC&GS, USGS, and CE. Aerial photography June 1951. Public land lines are based on the Gila and Salt River Meridian. Map field checked 1951 and 1952. This map complies with the national standard map accuracy requirements.

These textual versions explained, who made the map, from what source material and what methods were used. Study the above credit note and determine the date of the aerial photography that was used in making this map.

____

(NW NE
SW SE)

FRAME #12

Each quarter of the breakdown of the 1:50,000 sheet 5662II determines the boundary of a 1:25,000 scale map sheet. Thus 5662IINW indicates a map sheet which is prepared at a scale of 1:25,000.

How many 1:25,000 map sheets can be made from a sheet numbered 5561II?

(June 1951)

FRAME #37

The contour interval note is the vertical distance between contour lines on a map. The contour interval is extremely important to the map reader in determining elevations. Example:

CONTOUR INTERVAL 10 FEET

By looking at the example above we know that the distance between contour lines on the map represents a change in elevation of ______ ________ on the ground.

(4)

FRAME #13

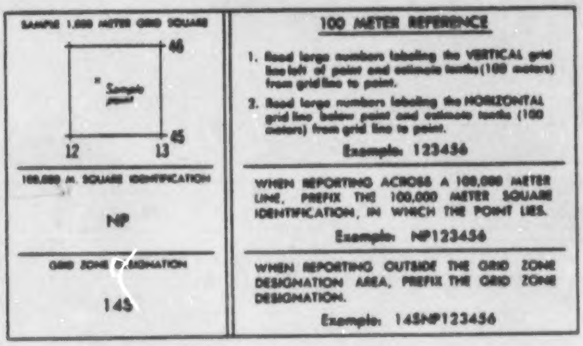
Using only the sheet number it is possible to tell exactly what scale a map sheet is. Write down what scale is represented by the following sheet numbers:

1. 4369: ________________
2. 4435IVSW: ________________
3. 6498II: ________________

(10 feet)

FRAME #38

The grid reference box is also part of the marginal data. This box is used to give instructions for obtaining grid references on the map. The box for a standard map sheet is shown below:



SAMPLE 1,000 METER GRID SQUARE

100,000 M. SQUARE IDENTIFICATION

NP

GRID ZONE DESIGNATION

14S

100 METER REFERENCE

1. Read large numbers labeling the VERTICAL grid line left of point and estimate tenths (100 meters) from grid line to point.
2. Read large numbers labeling the HORIZONTAL grid line below point and estimate tenths (100 meters) from grid line to point.

Example: 123456

WHEN REPORTING ACROSS A 100,000 METER LINE, PREFIX THE 100,000 METER SQUARE IDENTIFICATION, IN WHICH THE POINT LIES.

Example: NP123456

WHEN REPORTING OUTSIDE THE GRID ZONE DESIGNATION AREA, PREFIX THE GRID ZONE DESIGNATION.

Example: 14SNP123456

As a reference to read grid coordinates on a map, you would refer to the __________ __________ __________.

(1:100,000 - 1:25,000 - 1:50,000)

FRAME #14

In addition to the sheet name and sheet number there is also the series name. The series name is normally written with the scale of a map. The series name of a map is the geographic name of the area covered by a particular series of maps. If several series at the same scale are designated to cover a country or region they are identified by the country or region name. For example: Southern Honshu, Central Philippines, Northern Europe, etc. In most cases the country or state name will be used.

(grid reference box)

FRAME #39

The grid reference box also gives the Grid Zone Designation and the 100,000 Meter Square Identification for the map. These two identifications are a part of the Universal Transverse Mercator Grid System. What is the Grid Zone Designation and the 100,000 Meter Square Identification for the illustration in Frame #38?

(No response)

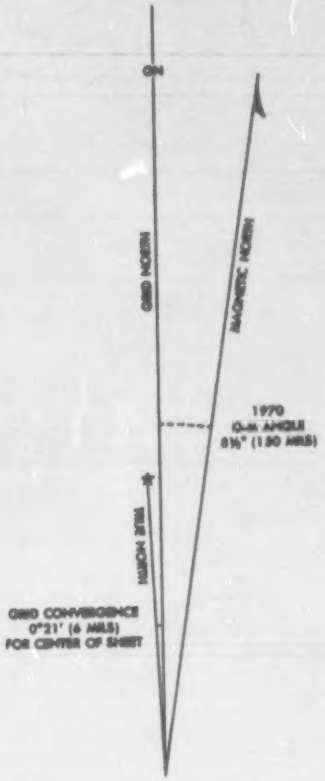
FRAME #15

It is important not to confuse sheet name with series name. The sheet name relates to a particular map while the series name relates an entire group of maps in a specified geographic area. If you were told Baltimore was the sheet name appearing on a map then Maryland would be the _______ _______ of the map.

(14S NP)

FRAME #40

The declination diagram on a map indicates the angular relationships between true, grid, and magnetic north. A typical declination diagram is shown below:


GN
GRID NORTH
MAGNETIC NORTH
1970
G-M ANGLE
8½° (150 MILS)
TRUE NORTH
GRID CONVERGENCE
0°21' (6 MILS)
FOR CENTER OF SHEET

How many North directions are indicated on this illustration?

(Series Name)

FRAME #16

In addition to the series name all topographic maps have a series number. An example of a series number is: V834

Many times there are more than one series of maps covering the same geographic area. For this reason each series is given an identifying number. Series numbers are used to distinguish different series covering the __________ ____________ ____________.

---

(3)

FRAME #41

Magnetic North is shown by a half arrow:

This prong represents the direction pointing to magnetic north in the declination diagram. Magnetic north is the direction that all compasses point to. The declination diagram indicates the variation in degrees, minutes and seconds between grid north and

______________.

(same geographic area)

FRAME #17

As with the sheet number, each part of the series number (V834) has a specific meaning and tells the map user something about the map. The first element of the series number may be either a numerical or letter designation, depending upon the scale and size of the area concerned. Numerals are used to indicate the continental area. Letters indicate the geographic region in which the series occurs. Medium and large scale maps have a letter designation as their first element and refer to a particular ___________ _____________.

____.

(magnetic north)

FRAME #42

Grid North is represented as a continuation line of the map grid that is broken and has the letters "GN" written in part of it. Grid north is the angular difference in direction between grid north and true north. It is measured east or west of true north. Grid north is represented in the declination diagram by the _______________ of a map grid line.

366 64

ka)

#20

he second entry of the series number is always a numerical index ating the scale group of a map. If the series number of a 1:25,000 heet were V834, we would expect all 1:25,000 scale maps to have ies number with the number ____________ as the second entry.

re

e

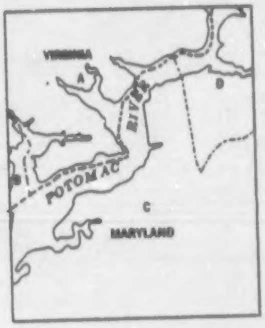
egrees, 51 minutes)

E #45

There are normally two diagrams within the marginal information first of which is the boundaries diagram. This diagram, which is niature of the map area, shows the boundaries that occur within map area. An example of such a diagram is shown below: (Not in or)

lian

INDEX TO BOUNDARIES



How many states would be portrayed on the map having this gram?

375

(No response)

FRAME #19

The letter breakdown for the entire world is shown on Plate 1. As you study this plate you will notice that the leter "V" locates the United States. What is covered by the letter "Q"?

(8 and one/half degrees)

FRAME #44

The declination diagram is also usually accompanied by notes that explain how to convert from one north direction to another. An example is shown below:

TO CONVERT A
GRID AZIMUTH TO A
MAGNETIC AZIMUTH
SUBTRACT G-M ANGLE

TO CONVERT A
MAGNETIC AZIMUTH
TO A GRID AZIMUTH
ADD G-M ANGLE

Using the diagram in Frame 40, what is the distance in degrees and minutes between magnetic north and true north?

(7)

FRAME #22

The third element is also always a numerical index and indicates the sub-regional area of the first element. In series number V834 the 3 indicates a sub-region of V. The exact sub-regions of the United States are shown on Plate 3. Using this diagram, what would the third index be if the map were of Florida?

(5661 III)

FRAME # 47

Adjoining sheets shown in the diagram by dashed lines are in a different series and have a different series number than that of the primary map. This new series number is always indicated in the diagram. Referring to the preceding Frame, how may maps have a series number different than the primary series number. What is/are their numbers?

367

(8)

FRAME #21

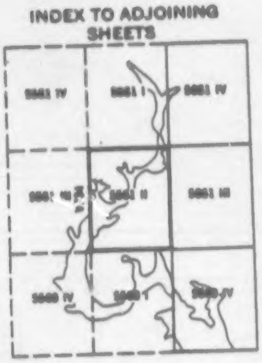
The exact scale groupings for the second entry of the series number is shown in Plate 2. Using this list as a reference, a 1:50,000 scale map would have what number for its second entry?

---

(2)

FRAME #46

Adjacent to the boundaries diagram is the Adjoining Sheets diagram. This diagram identifies the map sheets surrounding the map that the diagram is located on. An adjoining sheet diagram is shown below. The primary map sheet is in the center of the diagram and is indicated by a heavier line. To find the sheet number for the maps directly north, south, east or west of the primary map study the sheet diagram. The sheet directly east would be ____________. (Not in color)



378

(United States - City map - western sub-region)

FRAME #24

The fourth entry identifies the map you have from others having the same scale and area coverage. In effect, the fourth element established a series separation among unique series whose first three elements are identical.

(No response)

FRAME #49

All maps should contain a User Note. This note is important because it gives the people who work with the map an opportunity to refer errors or omissions to TOPOCOM who in turn use this information when evaluating a particular map sheet for recompilation or revision. Example:

USERS ARE URGED TO REFER CORRECTIONS AND COMMENTS FOR INCREASING THE USEFULNESS OF THIS GRAPHIC TO COMMANDING GENERAL, U.S. ARMY TOPOGRAPHIC COMMAND, WASHINGTON, D.C. 20315

(No response)

FRAME #25

It is possible to have a series number with 4 or more entries. The fifth entry is restricted to Photomaps and special purpose maps. For example: P indicates a plastic relief map: V834P.

(No response)

FRAME #50

All maps which are in the Department of Defense Map Supply System contain stock number identifications. The stock number consists of a 15 unit designation which represents, in sequence, the series number, sheet number and edition date. example:

STOCK NO. P773X47793***10

The first 5 units represent the series number "P773X". The letter "X" is shown as the 5th unit when the number has only 4 units. The next 8 units represent the sheet number "47793***". The symbol "*" is used with numbers less than 8 units. The last 2 units are used for the edition "10".

Return to the bottom of page 1 (LEVEL B) for Frame #26.

(No response)

FRAME #51

In addition to the general information we have discussed, it is possible to have special scales and notes added to a map to aid the map user. Some of this special information includes a glossary of foreign terms, security classification, coverage diagram, boundary notes, or any other kind of special note. Any additional marginal information that is added to a map should have one purpose: to ___ ___ ___ ___ ___.

(GO TO SELF TEST ON PAGE 27)

SELF TEST

Using the furnished map sheet, answer the following questions.

		FRAME
1.	What is the sheet name?	4
2.	What is the scale of the map?	14
3.	What is the number of the 1:100,000 sheet series this map falls within?	6
4.	What date was the map compiled?	35
5.	What is the sheet number of the sheet directly north of this sheet?	46
6.	What is the series number of the sheet directly south of this sheet?	16
7.	What grid zone is used on this sheet?	38
8.	What is the contour interval used on this map sheet?	37
9.	What do the black numbers in the water areas represent?	32
10.	How many counties are shown on this map?	45
11.	Who published this map?	36
12.	Given only the Stock No. E823X38844NE*02, identify the three components of the map sheet.	50

RESPONSE
FRAME #51 (aid the map user)

374

INDEX OF REGIONAL AREAS

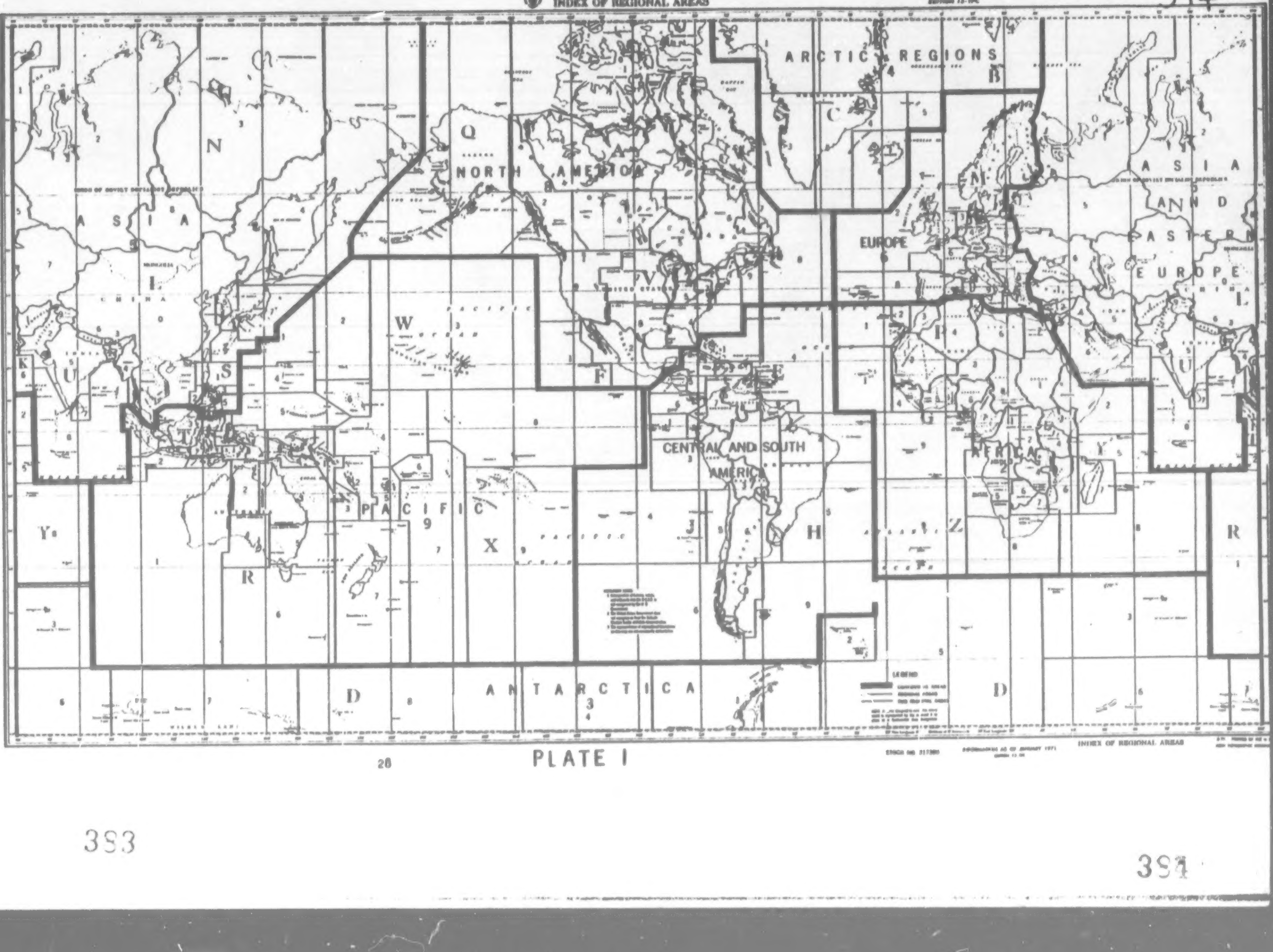

ARCTIC REGIONS
NORTH AMERICA
EUROPE
ASIA AND EASTERN EUROPE
ASIA
CHINA
AFRICA
CENTRAL AND SOUTH AMERICA
PACIFIC
PACIFIC OCEAN
ANTARCTICA
LEGEND
INDEX OF REGIONAL AREAS
N
Q
A
B
C
V
W
F
E
S
T
U
K
I
L
M
P
G
Y
R
X
J
H
Z
D

PLATE I

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SECOND ELEMENT	SCALE GROUP
1	1:5,000,000 and smaller
2	Larger than 1:5,000,000 through 1:2,000,000
3	Larger than 1:2,000,000 through 1:510,000
4	Larger than 1:510,000 through 1:255,000
5	Larger than 1:255,000 through 1:150,000
6	Larger than 1:150,000 through 1:70,000
7	Larger than 1:70,000 through 1:35,000
8	Larger than 1:35,000 (excluding city maps)
9	City maps (regardless of scale)
0	Photomaps (regardless of scale)

PLATE 2

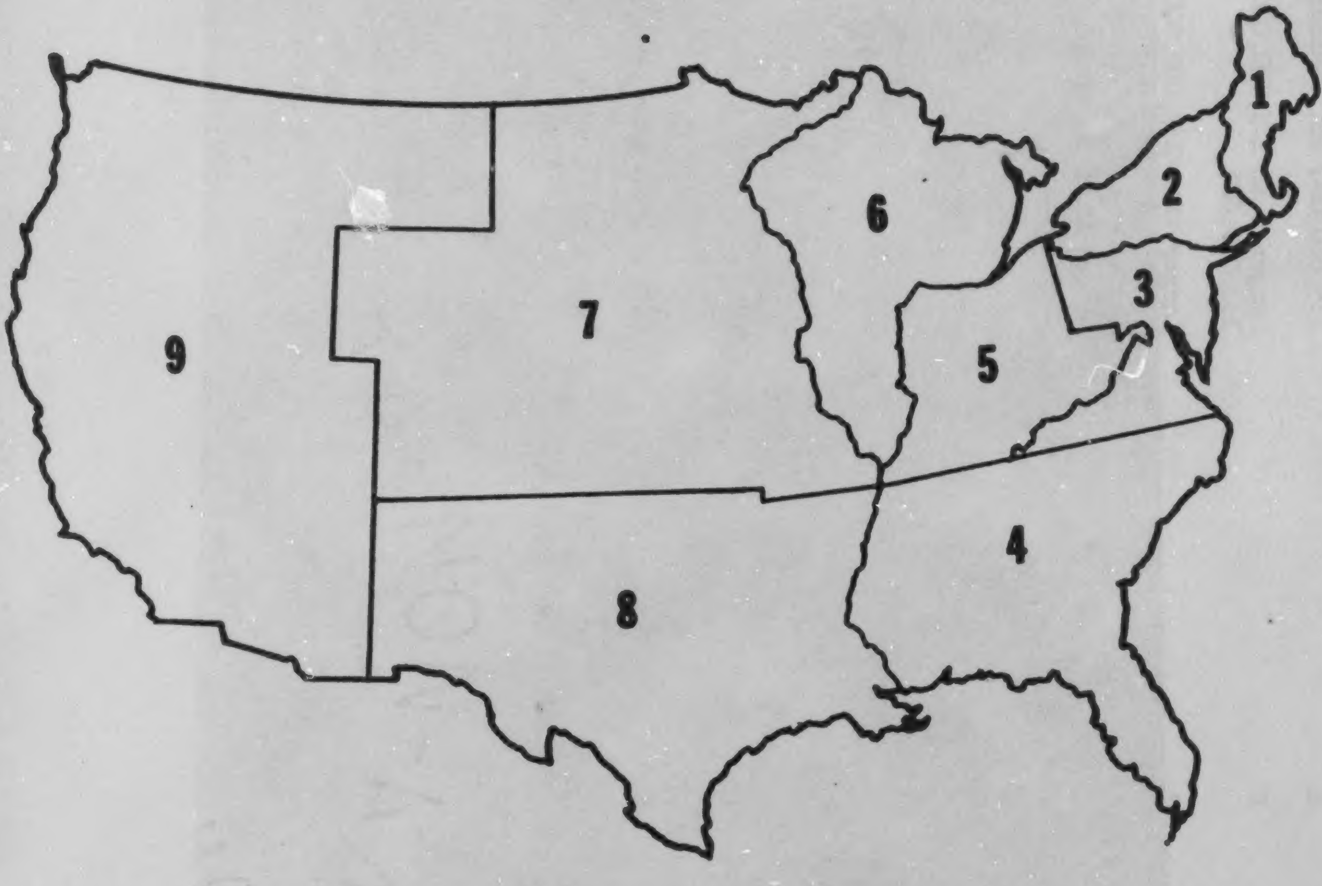

Plate 3

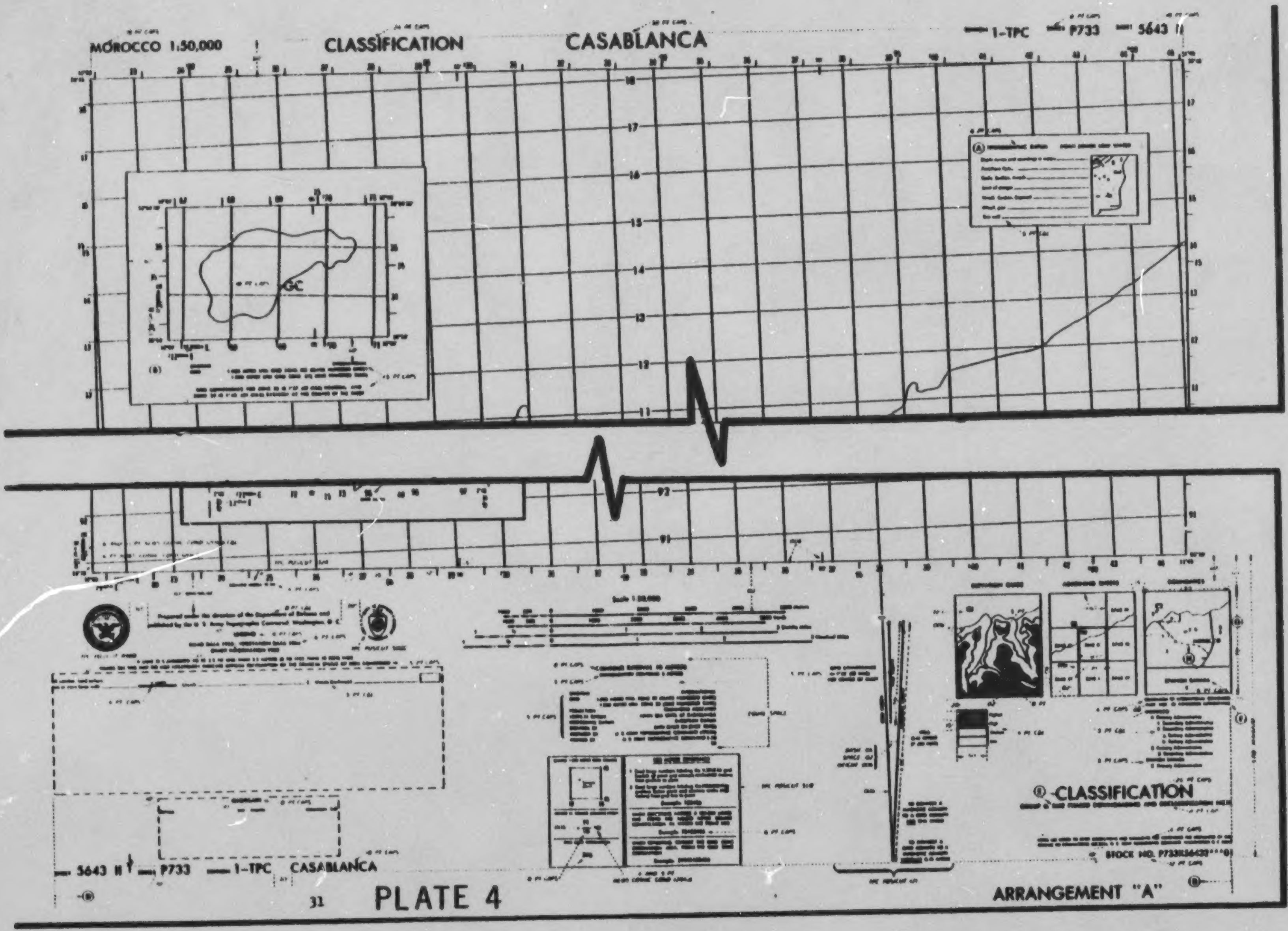
MOROCCO 1:50,000
CLASSIFICATION
CASABLANCA
1-TPC
P733
5643 II
GC
18
17
16
15
14
13
12
11
92
91
Scale 1:50,000
CLASSIFICATION
STOCK NO. P733X5643
5643 II
P733
1-TPC
CASABLANCA
ARRANGEMENT "A"

PLATE 4

45C20-C-010-010

PROGRAMED TEXT

COMMON SKILLS IN MAP READING

SEPTEMBER 1971

This edition includes change No. 3 dated 19 May 1975.

US ARMY ENGINEER SCHOOL - FORT BELVOIR, VIRGINIA

STOCK NUMBER: T.012-B0-PT-018

INTRODUCTION

This self-teaching text in map reading covers those skills needed by everyone who uses military maps and map substitutes. It provides a foundation for personnel whose training program will require specialized or more advanced skills. Study of this text should be supplemented by practical exercises in the field with map and compass.

The instructional material in this text consists of six parts. You should study them in the proper sequence — especially Parts I, II, and III. You will use what you learn about symbols, marginal information, point location, and distance measurement over and over again in subsequent parts. The six parts are as follows:

Part I.	Symbols and Marginal Information.
Part II.	Location
Part III.	Distance
Part IV.	Direction
Part V.	Relief
Part VI.	Map Supplements and Substitutes

ORGANIZATION OF TEXT

This text consists of **frames** and **panels**. A **frame** presents a single teaching point, which usually requires an answer to a specific problem. A **panel** is an illustration or other information needed to solve the problems in the frames.

The problem in some frames requires you to write an answer. In others, you select a correct choice and draw a circle around it. A few frames are called INFORMATION or REVIEW frames and do not need an answer. When the frame refers you to a panel, find the correct panel (printed after the frames) and study it before answering the question.

HOW TO STUDY

1. Start with frame 1 in Part I. Answer it correctly by drawing a circle around the correct choice in pencil.

2. Turn the page. The correct answer to frame 1 is printed in parentheses above frame 2 on page 1-3. If you were incorrect, turn back to frame 1 to re-study the frame and change your answer to the correct one. (Correcting wrong answers will help you remember the teaching point.)

3. Answer frame 2 by filling in the blanks with the correct words.

4. Turn the page. Check your answer as before and then work out frame 3 and continue in the same manner.

MATERIALS FURNISHED

You receive considerable practice with actual map-reading materials in this instruction. The following materials are essential in answering the frames in this text:

Topographic map: Kansas, 1:50,000, Leavenworth, Sheet 7062 IV

Photomap: Kansas photomaps, 1:50,000, Leavenworth, Sheet 7062 IV (Printed on back of Leavenworth topographic map.)

Pictomap: Virginia, 1:25,000, Fort Belvoir and Vicinity, Special Map

(NOTE: Disregard the photomap and topographic map printed on the back of the furnished pictomap. References in this text to the Fort Belvoir and Vicinity Special Map are to the **Pictomap** only.)

Aerial photograph "A", M-109, Exposure 565

Map reading overlay, keyed to the Leavenworth topographic map.

Protractor with map scales

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PART I

SYMBOLS AND MARGINAL INFORMATION

Set 1-1. TOPOGRAPHIC SYMBOLS

FRAME 1.

A topographic map is a drawing of part of the earth's surface. Rivers, roads, woods, and hills are shown by lines, symbols, and colors. What is a military topographic map?

a. picture b. drawing

(brown) (11)

FRAME 12.

You are already "recognizing" roads, railroads, towns, swamps, and orchards. Even though the map is a drawing, it helps you "see" the ground from above. Find the same section of State Route 92 in the photomap printed on the reverse side of the map. Which view permits you to "see" State Route 92 more clearly?

a. topographic map b. photomap

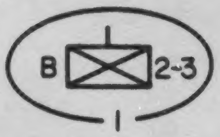
(b.) (22)

FRAME 23.

Certain Army units are identified by the Combat Arms Regimental System (panel 1-2). Under this system, the parent units are designated by both battalion and traditional regimental numbers. Under the Combat Arms Regimental System (CARS) both battalion and traditional ________________ numbers are shown.

---

(33)



FRAME 34.

Refer to panels 1-4B and 1-5B and the Map Reading Overlay provided with this text. In which area is the minefield located?

a. friendly

b. enemy

(b. drawing) (1)

FRAME 2.

Study the colors on the LEAVENWORTH map. Notice that five colors are used on it. As you would expect, blue shows water features and green shows vegetation. Brown shows elevations (hills and valley). The colors __________ and __________ show manmade features, such as highways and buildings.

(a. topographic map) (12)

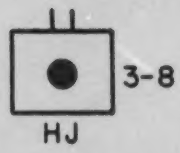
FRAME 13.

Manmade features (roads, buildings) are extremely important in planning military operations. The map maker wants you to "see" them clearly so he draws them a little larger than they would be on a photo. He uses colors and symbols. He is careful, however, to position the centers of the symbols correctly. The size of manmade features, such as roads and buildings, is often exaggerated on a map so the reader can ______________ them better.

(regimental) (23)

FRAME 24.

In writing the CARS symbol, **battalion** and **regimental** numbers are written together separated by a **dash**, for example 3-8. In the symbol below 3 means the 3d Battalion and 8 means the 8th ________________.



(a. friendly) (34)

FRAME 35.

Refer to Panel 1-4B and the Map Reading Overlay. On the overlay, find circles with an X inside. What do these military symbols mean?

a. supply points
b. infantry headquarters
c. coordination points

(red, black) (2)

FRAME 3.

Bright red describes the main roads shown on the map. What does the lighter shade of red on the LEAVENWORTH map show?

a. railroads

b. churches and post offices

c. built-up areas

(see) (13)

FRAME 14.

FM 21-31, Topographic Symbols, defines approximately 250 symbols used by the map makers. However, the map legend contains all the symbols normally required by the map reader. When you find a topographic symbol that is neither self-explanatory nor explained in the legend, you should refer to FM __________-__________ if you need to know what it means.

(regiment) (24)

FRAME 25.

Draw the symbol for Company A, 8th Battalion, 33d Armor, 21st Armored Division, using the CARS system.

(c. coordination points) (35)

FRAME 36.

You are beginning to "see" troop units, supply points, minefields, and boundary lines in the military symbols drawn on a situation map or overlay. Since you cannot expect to memorize all such symbols before you begin using them, you use FM _______-_______ as a reference when necessary.

399

(c. built-up areas. Otherwise, a city would appear in black because of the symbols for buildings and would be hard to read.) (3)

FRAME 4.

You have learned that 5 colors are used on a large-scale topographic map to show the different features on the earth's surface. Write the correct color or colors in the space after each of the following:

a. woods and orchards ____________

b. contour lines ____________

c. rivers and lakes ____________

d. roads ____________ and ____________

e. built-up areas ____________

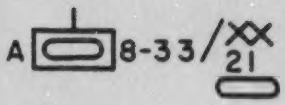
Set 1-2. MILITARY SYMBOLS

(21-31. Memorizing all topographic symbols before you need them is impractical. You will learn them more effectively through usage.) (14)

FRAME 15.

The military map user often wants to "see" the military situation — location of friendly and enemy units, command posts, observation points, supply points, weapons, defenses, unit boundaries, and so on. These are shown by military symbols. A situation map shows a tactical or administrative situation on the ground by what kind of symbols?

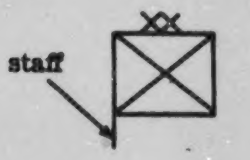
a. topographic   b. military



(25)

FRAME 26.

Field headquarters of units (Panels 1-1 and 1-4a) are shown by the symbol with a staff attached as shown below. The end of the staff indicates the exact location. The unit symbol with ______________________________ indicates a field headquarters.



Set 1-3. MARGINAL INFORMATION

(21-30) (36)

FRAME 37.

On the LEAVENWORTH map, you found the map symbols in the marginal information. Later, the marginal information will help you locate points, measure distance, and find directions and elevations. The map reader needs to understand and use ______________________ information correctly.

(a. green; b. brown; c. blue; d. red and black; e. red) (4)

FRAME 5.

The symbols and colors used on a military map are explained in the legend. Find the legend on the LEAVENWORTH map. In what part of the map margin is the legend located?

a. top center   b. lower left

(b. military) (15)

FRAME 16.

Panels 1-1 through 1-5 printed at the end of Part I show the military symbols commonly used on situation maps and overlays. They are extracted from FM 21-30. Once you learn the system, you recognize symbols with practice. When you find one that you do not understand, you should look it up in FM _____-_____.

(staff) (26)

FRAME 27.

In the space below, draw the symbol for an infantry company headquarters.

(marginal) (37)

FRAME 38.

In addition, marginal information enables you to identify maps so that you can requisition them properly and be sure that all users are referring to the same sheets. Specific military maps can be identified by referring to the ____________________ information.

(b. lower left) (5)

FRAME 6.

Refer to the LEAVENWORTH map. Find where the Chicago, Burlington, and Quincy Railroad enters the map from the south (bottom right). What does the symbol tell you about this railroad?

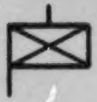
a. single track b. multiple track

(21-30) (16)

FRAME 17.

Refer to Panel 1-1. What is the shape of the symbol denoting a military unit, such as a company, battalion, or division?

a. round b. triangular c. rectangular

() (27)

FRAME 28.

A field headquarters is shown by the unit symbol and a ________________ which indicates the unit's exact location.

(marginal) (38)

FRAME 39.

Each map is called a sheet by the map makers. The sheet is named after the most prominent feature shown on the map. The sheet name is printed in the top center margin. Refer to your LEAVENWORTH map. The sheet name is ____________________.

(b. multiple track) (6)

FRAME 7.

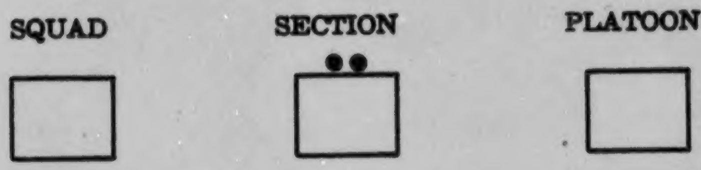
Refer to the LEAVENWORTH map. Follow the Chicago, Burlington, and Quincy Railroad upwards past Horseshoe Lake and the town of Farley. Before you get to Green Cemetery there is some swamp or marsh on the left side of the tracks. What tells you this is a swamp?

a. symbol and color   b. words

(c. rectangular) (17)

FRAME 18.

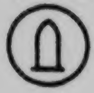
Symbols indicating the size of the unit are placed at the top of the rectangle. Small units of squad, section and platoon size are shown with 1, 2, or 3 dots respectively. Refer to Panel 1-1. Complete the appropriate size identifications on the troop units shown below by putting the right number of dots over the squad and platoon symbols.

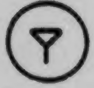


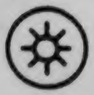
(staff) (28)

FRAME 29.

Refer to Panel 1-3. Which of the following symbols shows an ammunition supply point?

a. 

b. 

c. 

(Leavenworth) (39)

FRAME 40.

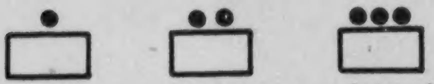
The series name defines the larger geographic area covered by a group of sheets. It is often a state or a country. The series name is printed in the upper left margin. Refer to the LEAVENWORTH map. Its series name is ____________.

407

(a. symbol and color) (7)

FRAME 8.

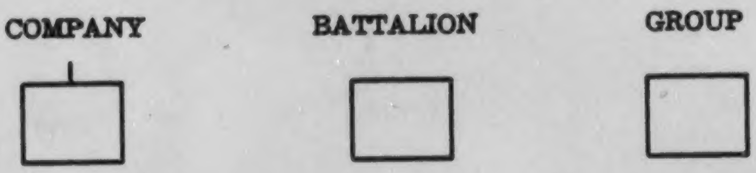
You were able to identify the symbol for a swamp area by checking the ________________ in the lower left margin of the LEAVENWORTH map.

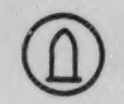


(squad section platoon) (18)

FRAME 19.

One, two, or three short vertical lines indicate units of company, battalion, and group (or regiment) size. Refer to Panel 1-1. Place the correct number of vertical lines over the battalion and group symbols.



(a. ) (29)

FRAME 30.

Refer to the overlay furnished with this text. When this overlay is correctly placed over the LEAVENWORTH map, it shows a tactical situation on the northwest (upper left) portion of the map. The military situation is shown on the overlay by __________ __________.

(Kansas) (40)

FRAME 41.

To shorten the sheet name and series name identification, a **sheet number** is printed in the upper right corner of the map. On very recent maps, it is also shown in the lower left corner. Refer to the LEAVENWORTH map. The sheet number for the Leavenworth, Kansas 1:50,000 map is ______________.

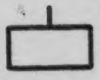
409

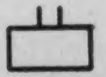
(legend) (8)

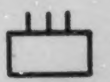
FRAME 9.

Refer to the left edge of the LEAVENWORTH map. Find where State Route 92 enters the map and trace it to the top of Knob Ridge (just before it turns right into Leavenworth). What tells you this is a state route rather than a Federal route?

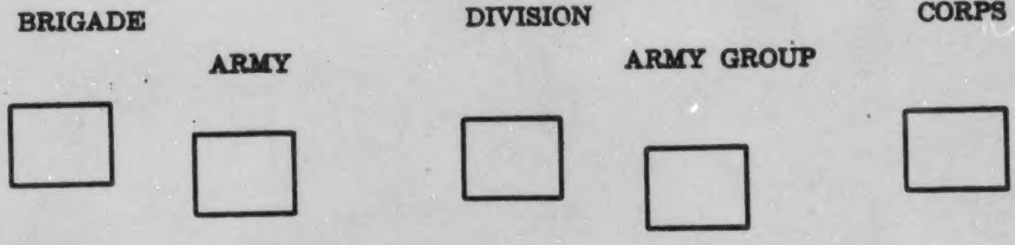
a. color b. symbol


(company


battalion


group) (19)

Larger units are identified by one or more letters X. Refer to Panel 1-1. Place the appropriate size identification on the units indicated below as required.



400

(military symbols) (30)

FRAME 31.

Panels 1-4 and 1-5 describe the main military symbols used on situation maps and overlays. From Panel 1-4 and other panels, draw the symbol which would show the future location of the 2d Infantry Bn Headquarters.

(7062 IV) (41)

FRAME 42.

In the lower right corner of the LEAVENWORTH map is a diagram showing the Index to Adjoining Sheets. It identifies the sheet numbers surrounding your map. Note that sheet number of the LEAVENWORTH map, 7062 IV, is in the heavily outlined box. If you needed the sheet to the left of your map you would ask for sheet number ________.

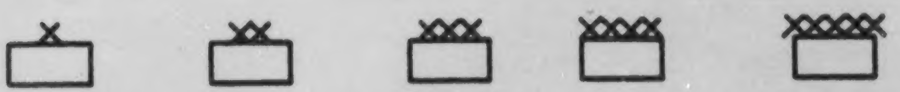
411

(b. symbol) (9)

FRAME 10.

Refer again to State Route 92 on the LEAVENWORTH map. On the right side of the road just above the word Knob is an orchard. How do you know this is an orchard instead of a vineyard or a woods?

a. color **b.** symbol

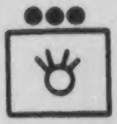


(brigade division corps army army group) (20)

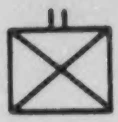
FRAME 21.

In addition to size, the arm or branch of service of the unit is indicated by a symbol inside the rectangle. Refer to Panel 1-1. Which of the following symbols represents an artillery battalion?

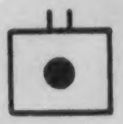
a.

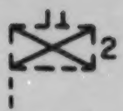


b.



c.

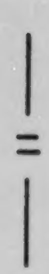


() (31)

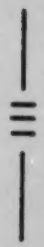
FRAME 32.

Refer to Panel 1-4D. On a situation map, which of the following would show the boundary between two battalions?

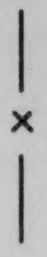
a.



b.



c.



(6962 I) (42)

FRAME 43.

Examine the numbering and you will see four "7062" maps in a group. The upper right one is labeled I and the others increase clockwise (II, III, and IV). To the left of 7062 IV is 6962 I. What is the sheet number of the next sheet to the left of 6962 I?

a. 6962 III b. 6962 IV c. 6862 I d. 7062 IV

(b. symbol) (10)

FRAME 11.

Refer again to the orchard near State Route 92. In the eastern (right) half of the orchard, find the figure 1100 inserted in a brown line. This means that the hill along that particular line is 1100 feet above sea level. You can tell that the 1100 means elevation rather than something else because the number is printed in a ________________ color.

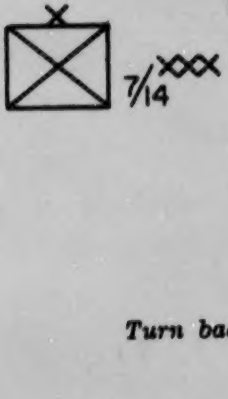
Turn back to bottom of page 1-1 for frame 12

(c. . The round black dot means artillery and the two lines indicate a battalion.) (21)

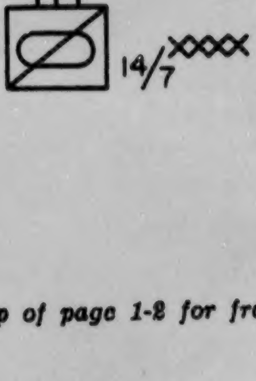
FRAME 22.

Refer to Panels 1-1 and 1-2. Using what you learned in previous frames, which of the following symbols would identify the 14th Armored Cavalry Regiment, 7th Army?

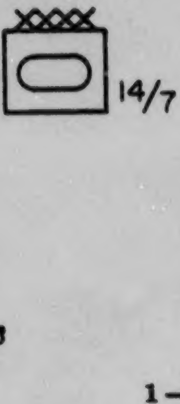
a. a.



b. b.



c. c.



Turn back to top of page 1-2 for frame 23

(a.) (32)

FRAME 33.

Again refer to Panel 1-4D. Draw the symbol that would show the defensive area held by B company, 2d Battalion, 3d Infantry.

Turn back to bottom of page 1-2 for frame 34

(b. 6962 IV. If you didn't select this answer, the diagram below illustrates the numbering.) (43)

6963 III	6963 II	7063 III	7063 II
6962 IV	6962 I	7062 IV	7062 I
6962 III	6962 II	7062 III	7062 II

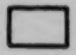
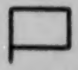
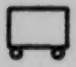
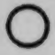
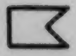
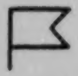
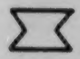
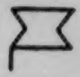
FRAME 44.

In addition to the sheet number, a series number assigned by the U. S. Army Topographic Command (TOPOCOM) gives coded information about the map sheet, such as the region of the earth where it falls, and the scale of the map. The series number is printed beneath or next to the sheet number. The series number of the LEAVENWORTH map is ______ 415

PANEL 1-1

UNITS AND INSTALLATIONS

Geometric figures form the basic symbols used to represent units and installations. Examples of the more common figures are as follows:

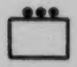
A unit (a rectangle)	
A field headquarters or headquarters echelon of a unit (Staff is always to the left)	
An observation or listening post	
Combat service support elements of U. S. combat units (brigade trains and below)	
A logistical installation or activity:	
A combat service support unit that performs duties as a part of a field army support command	
A headquarters or headquarters echelon of a field army support command combat service support unit. (Staff is always to the left)	
A combat service support unit that performs duties within the communications zone	
A headquarters or headquarters echelon of a combat service support unit within the communications zone	

SIZE INDICATION

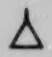
To show the size of a specific unit or activity, the appropriate size indication is placed on top of the basic symbol.

Squad	●
Section or unit larger than squad but smaller than a platoon.	● ●
Platoon or Detachment	● ● ●
Company, Battery, or Troop	I
Battalion or Squadron	II
Group or Regiment	III
Brigade or Equivalent Command	X
Division	XX
Corps	XXX
Army	XXXX
Army Group	XXXXX

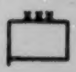
Examples:



(A platoon)

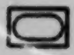
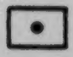
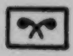
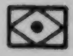
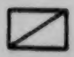
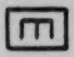
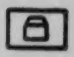
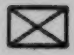
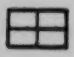
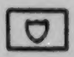
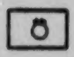
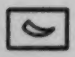
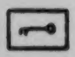
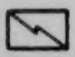
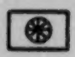
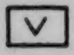


(A company observation post)



(A corps headquarters)

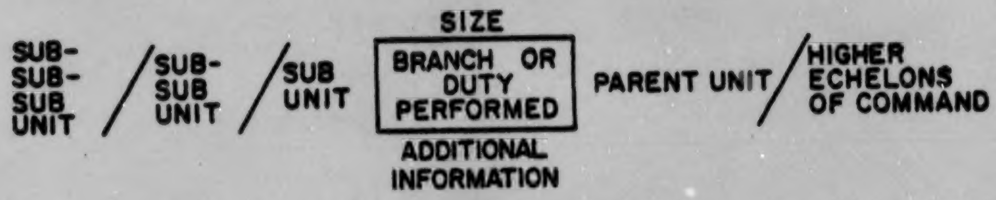
ARM OR BRANCH OF SERVICE

Arm or Branch	Symbol
Armor	
Army Security Agency	ASA
Artillery	
Chemical (CBR)	
Coast Artillery (Foreign Armies only)	
Cavalry (Reconnaissance)	
Engineer	
Finance (Pay)	
Infantry	
Medical	
Military Intelligence	MI
Military Government or Civil Affairs	
Military Police	MP
Ordnance	
Postal	
Quartermaster	
Signal	
Transportation	
Veterinary	

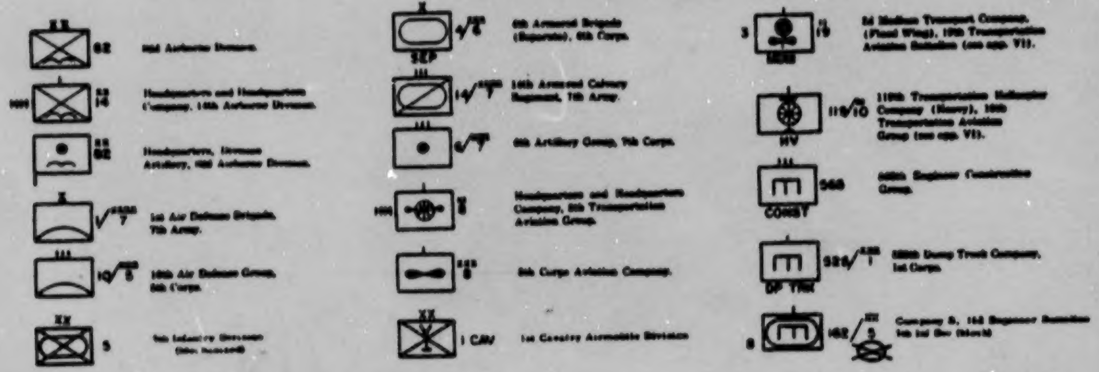
PANEL 1-2

UNIT DESIGNATION AND BASIC SYMBOL

To indicate a particular unit or installation, *the parent unit designation is placed immediately to the right of the basic unit or installation symbol;* additionally, the parent unit may be underlined. Higher echelons of command follow to the right of the parent unit designation. To the left of the basic symbol, subordinate units are shown. Slashes separate command echelons. Only cardinal numerals are used. The arrangement of various combinations of symbols to depict specific units or installation is shown in the following diagram:


SUB-SUB-SUB UNIT
SUB-SUB UNIT
SUB UNIT
SIZE
BRANCH OR DUTY PERFORMED
ADDITIONAL INFORMATION
PARENT UNIT
HIGHER ECHELONS OF COMMAND

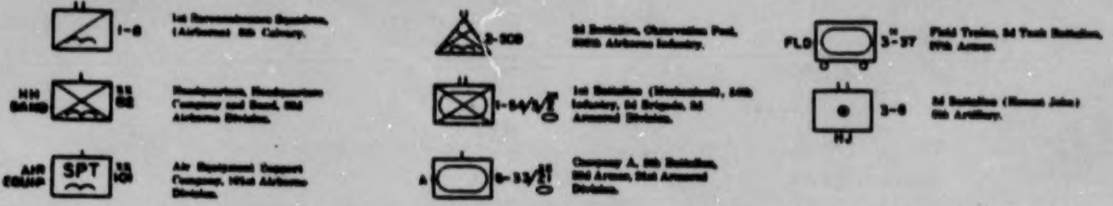
If only one type of unit is assigned to a military organization and if the unit is adequately identified by other military symbols, its designation may be omitted.


82
SEP
1 CAV
HV
CONST
568
DP TRK

PANEL 1-2 (Continued)

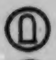
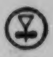
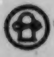
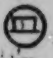
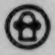
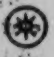
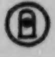
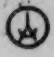
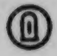
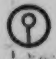
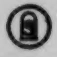
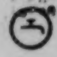
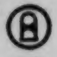
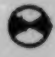
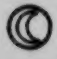
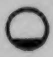
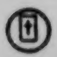
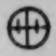
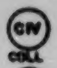
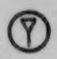
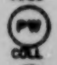
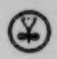
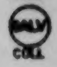
COMBAT ARMS REGIMENTAL SYSTEM (CARS)

Sometimes, parent units are identified by a combination of unit designations. Such a procedure is employed by many units within the U. S. Army and is known as the *Combat Arms Regimental System (CARS)*. Under the CARS system, parent units are designated by both the battalion (squadron) and traditional regimental numbers. To avoid confusion with different levels of command, *both numerical designations are always written together and separated by a dash rather than slashes.*



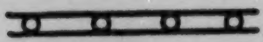
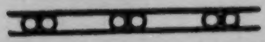
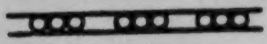
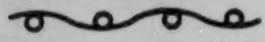
PANEL 1-3

LOGISTICAL AND MEDICAL INSTALLATIONS

Designation	Symbol	Designation	Symbol
Ammunition — any type		Petroleum, oils and lubricants — Army — Aviation	
Ammunition — Air Force		Solid fuel	
Ammunition — Army Aviation		Repair parts	
Ammunition — Artillery		Topographic	
Ammunition — rocket and guided missile		Traffic	
Ammunition — special		Water	
Ammunition — small arms		Parking	
Food Supplies		Class II and IV	
Graves service		Collecting points:	
Hospital, aid station		a. Civilian	
Petroleum, oils and lubricants		b. Prisoner of war	
Petroleum, oils and lubricants — Air Force		c. Salvage	

PIPELINES

Pipelines for refined petroleum products (indicate size in inches, if required) are shown as:

a. One line	
b. Two lines	
c. Three lines	
d. Submerged (one line)	

PANEL 1-4A

SITUATION MAPS AND OVERLAYS

COLORS

a. Colors in conjunction with military symbols denote the following:

(1) Blue or *Black*	— Friendly units, installation, equipment, and activities.
(2) Red	— Enemy units, installations, equipment, and activities.
(3) Yellow	— Friendly or enemy areas of chemical, biological, or radiological contamination.
(4) Green	— Friendly or enemy man-made obstacles.

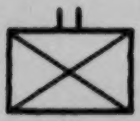
b. If other colors are used, a suitable explanation in the margin or legend is given.

PRESENT AND PROPOSED LOCATIONS

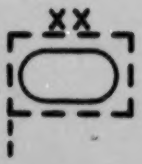
Basic unit and installation symbols are drawn with either solid or broken lines. The lower left-hand corner of the symbol indicates the location.

a. A solid line represents a present or actual location.
b. A broken line indicates a future or projected location.

Examples:



(The location of an infantry battalion)

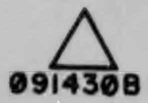


(The projected location of the headquarters of an armored division)

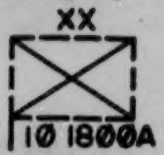
DATE-TIME GROUPS

Dates and times such as the opening of an installation or the expected arrival of a unit in a new location may be written under or inside the symbol. Date-time groups are used:

Examples:



(Present location of an observation post which opened at 1430 hours, Time Zone B, the 9th of the month).

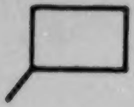


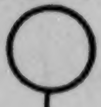
(Future location of the headquarters of an infantry division which is scheduled to open at 1800 hours, Time Zone A, the 10th of the month).

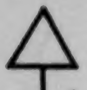
PRECISE LOCATIONS

Basic symbols other than the headquarters symbol may be placed on a central staff which is extended or bent as required. The end of the staff indicates exact location.

Examples:







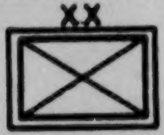
PANEL 1-4B

ENEMY FORCES

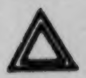
a. In general, the symbols shown in this manual are adequate for depicting both enemy and foreign units, weapons, equipment, and activities. When representing unorthodox units and equipment, the most appropriate symbol contained herein should be selected.

b. If only one color is available, enemy symbols are outlined with double lines.

Examples:



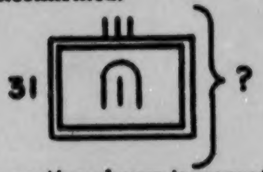
(Enemy infantry division)



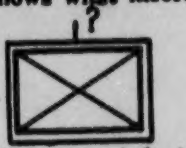
(Enemy observation post)

c. A question mark used in conjunction with an enemy symbol indicates unknown or unconfirmed information. The position of the question mark shows what information is unknown or unconfirmed.

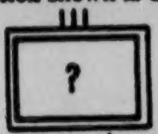
Examples:



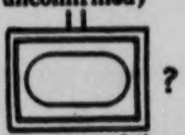
(All information shown is unconfirmed)



(The size of the enemy infantry unit is unconfirmed)



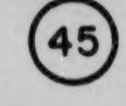
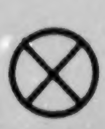
(The type of enemy regiment is unknown)



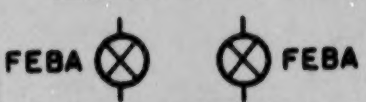
(The unit designation of the enemy tank battalion is unknown)

CONTROL POINTS

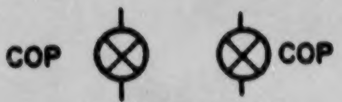
Control points are drawn on the selected terrain feature and identified as shown below.

Explanation and Remarks	Symbol
A *check point* consists of a circle inclosing a selected terrain feature with a number placed inside the circle	
A coordination point is shown by drawing a circle on the selected terrain feature and placing an "X" in the center. Coordination points are used in conjunction with boundaries to designate defensive areas.	

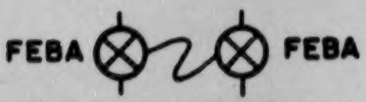
Examples:



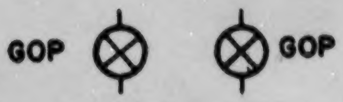
Forward Edge of the Battle Area.



Combat Outpost



Trace of the Forward Edge of the Battle Area.



General Outpost

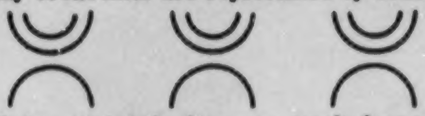
PANEL 1-4C

SITUATION MAPS AND OVERLAYS

FRONT LINES

a. Front lines are marked by a series of lines which curve away from opposing forces. If only one color is used, enemy front lines are represented by double lines.

Example:



b. Thinly held or patrolled parts of the lines are marked as a series of dots. If only one color is used, thinly held enemy lines are represented by open dots. The dots do not indicate strength or location of patrols.

Example:

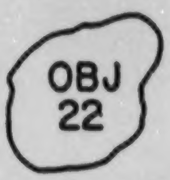
○ ○ ○ ○ ○ ○ ○

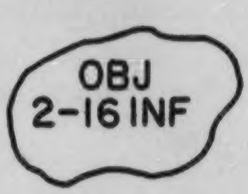
● ● ● ● ● ● ●

OBJECTIVES

Objectives and intermediate objectives are inclosed and identified by the abbreviation OBJ and a number, letter, code name, or unit designation.

Examples:

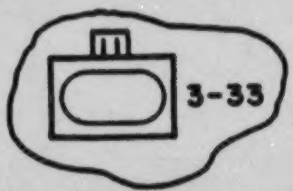




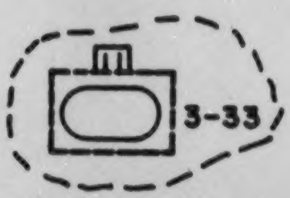
ASSEMBLY AREAS (UNDEFENDED AREA)

Assembly areas are inclosed and the unit symbol is placed in the center. Proposed assembly areas are shown with broken lines.

Examples:



(Assembly Area, Task Force, 3d Tank Battalion, 33 Armor)



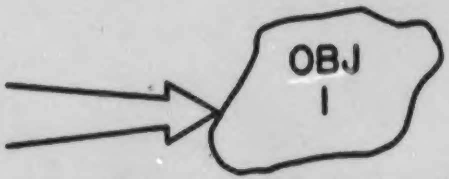
(Proposed Assembly Area, Task Force, 3d Tank Battalion, 33 Armor)

PANEL 1-4C (Continued)

AXIS OF ADVANCE

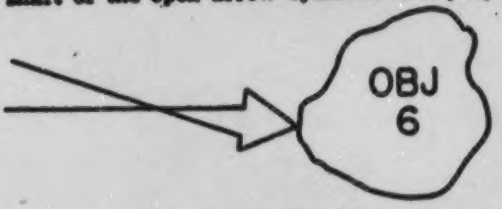
a. An axis of advance is normally assigned a code name or unit designation. The open arrow indicates the general route to be followed. A proposed axis of advance is shown in broken lines and labeled with the time or condition when effective. The point of the arrow touches the objective.

Example:



b. To differentiate between a ground axis of advance and an *air assault axis-of advance*, a twist is placed in the shaft of the open arrow symbolic of a propeller.

Example:

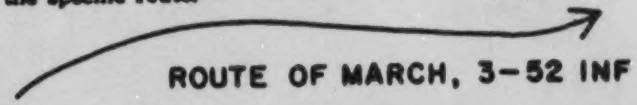


(Air Assault Axis of Advance)

DIRECTION OF ATTACK AND ROUTES OF MARCH

A direction of attack arrow is not labeled. Routes of march (advance, withdrawal, main supply, etc.) however, are labeled with their purpose and code name or unit designation. The arrow follows the specific route.

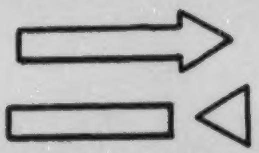
Example:



CONVOYS

a. Convoys of vehicles are represented by an arrow in the direction of movement; the point of arrow indicates the location of the head of the column.

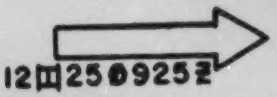
Examples:



(If the convoy is halted, the arrow is shown facing toward the rear of the column)

b. This symbol may be shown with the appropriate vehicle symbol to indicate the type and number of vehicles in the column. Likewise, the date and time may be added.

Example:



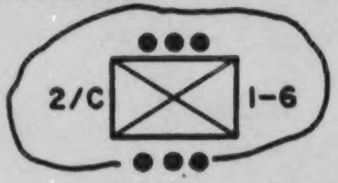
(A column of 12 medium tanks at 0925 Z hours on the 25th)

PANEL 1-4D

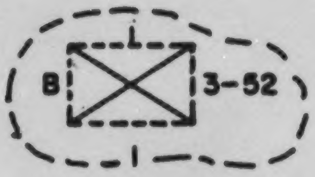
DEFENDED AREAS

If an area is occupied and defense of the area is prepared, a line including the size symbol of the defending unit incloses the area; the closed side of the symbol is oriented toward the most likely enemy threat. If desired, the military symbol of the defending unit may be entered in the center of the inclosed area.

Examples:



(Defensive area, 2d Platoon, C Company, 1st Battalion, 6th Infantry)

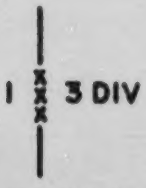


Proposed (Defensive area, B Company, 3d Battalion, 52d Infantry)

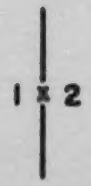
LATERAL BOUNDARIES

Boundaries are marked by a solid line with the size indication of the unit shown at convenient intervals. The designations of units supplemented by arm or branch and national designation, if necessary, are placed on either side of the size indication. If a lateral boundary separates units of unequal size, the symbol for the larger is used.

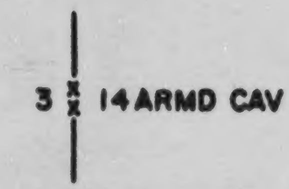
Examples:



(Boundary separates 1st Corps and 3d Division)



(Boundary separates 1st and 2d Brigades)

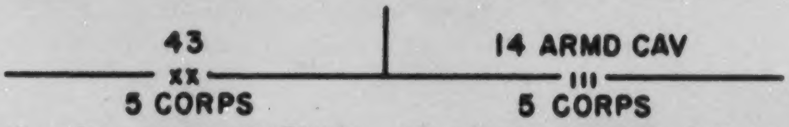


(Boundary separates 3d Division and 14th Armored Cavalry Regiment)

REAR BOUNDARIES

If a rear boundary is shown, the size indication along the boundary corresponds to the smaller unit or, in other words, to the commanded unit and not the commanding unit. Arm or branch and nationality of units are shown when required to prevent confusion.

Examples:

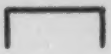
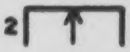
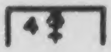
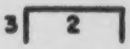
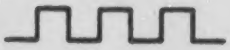


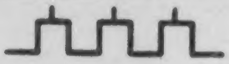
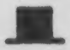
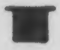
(Rear boundary separates 43d Division and 5th Corps) (Rear boundary separates 14th Armored Cavalry Regiment and 5th Corps)

PANEL 1-5A

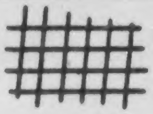
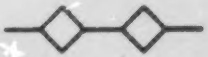
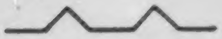
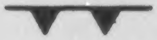
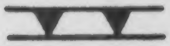
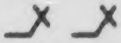
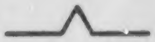
FORTIFICATION AND OBSTACLE SYMBOLS

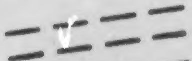
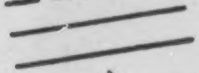
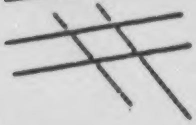
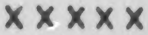
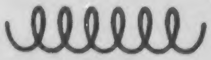
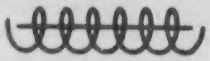
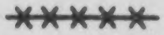
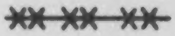
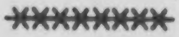
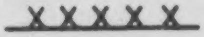
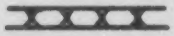
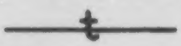
FORTIFICATION SYMBOLS

Fortification	Symbol
Weapon slit, foxhole or emplacement	
Two emplacements of light machine guns	
Emplacement for a four-barreled heavy machine gun	
Three foxholes for two men	
Any trench system	

Fortification	Symbol
Trench with firing bays	
Dug-out	
Surface shelter (above ground)	
Underground shelter	
Pill box or casemate	

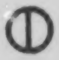
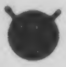
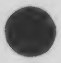
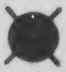
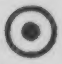
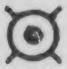
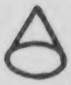
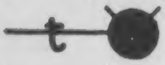
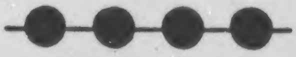
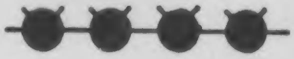
OBSTACLES OTHER THAN MINES

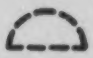
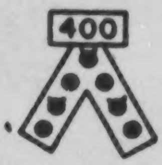
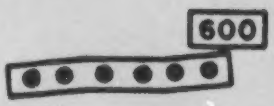
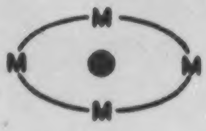
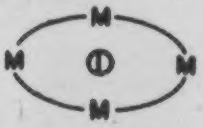
Obstacle	Symbol
Demolished area	
Tank obstacle, type unspecified	
Tank wall or bank	
Tank ditch	
Tank ditch covered	
Stakes, or rails or similar obstacles	
Tetrahedron, dragons' teeth and other similar obstacles	
Fixed	
Fixed and prefabricated	
Movable	
Movable and prefabricated	

Obstacle	Symbol
Road blocks, craters, and blown bridges:	
Proposed	
Prepared but passable	
Completed	
Wire	
Type unspecified	
Concertina, single	
Concertina, multiple	
Single fence	
Double fence	
Double apron fence	
Low wire fence	
High wire fence	
Tripwire	

PANEL 1-5B

MINES

Explanation of Symbol	Symbol
Mines, type unknown	
Mines, antipersonnel	
Mines, antitank	
Mines, antitank, boobytrapped	
Double antitank mines	
Boobytrapped double antitank mines	
Boobytraps	
Antipersonnel mines connected to tripwire	
Row of antitank mines	
Row of antipersonnel mines	

Explanation of Symbol	Symbol
Cluster of mines	
Minefield	
Minefield of 400 mixed antitank and antipersonnel mines	
Minefield of 600 antitank mines	
Boundaries	
Unfenced antitank minefield	
Unfenced with type of mines unknown	

PART II

LOCATION

Set 2-1. POINT LOCATION BY GRID COORDINATES

FRAME 1.

A grid is a network of evenly spaced horizontal and vertical lines. These lines form squares on a military map to help locate points (targets, road junctions, command posts, and so on) quickly and accurately. The grid on a map consists of squares formed by ______________ and ______________ lines.

(a. 3553 (If you marked 5335 you made the mistake of placing the northing number first)) (14)

FRAME 15.

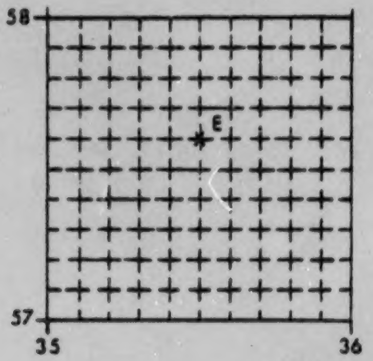
Find the Federal Penitentiary located just north of the city of Leavenworth. What are the grid coordinates of the grid square in which most of the penitentiary is located?

a. 3256 b. 3355 c. 3454

(a. 352578) (28)

FRAME 29.

Practice what you have learned about writing grid coordinates. Write the 6-digit coordinates for point E. ____________________



(b. 3855) (42)

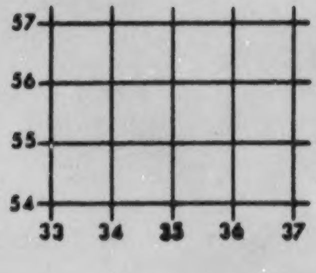
FRAME 43.

The 6-digit coordinates locate points on the LEAVENWORTH map to within 100 meters of their actual location on the ground. Writing 8-digit coordinates gives 10-meter accuracy. In 8-digit coordinates the 4th digit is added to the left-to-right reading and the 8th is an addition to the ____________________ reading.

(horizontal, vertical) (1)

FRAME 2. INFORMATION FRAME.

The horizontal and vertical lines are numbered in sequence. In the figure below, the vertical grid lines are numbered 33, 34, 35, 36 and 37, reading to the east from left to right. Because they measure distances eastward they are called "eastings". Reading north, from the bottom up, the horizontal grid lines are numbered 54, 55, 56, and 57. Because these horizontal lines measure distances northward, they are called "northings".



(b. 3355 (Grid line 33 (to the right) and 55 (up) cross at the lower left corner of the grid square in which the major part of the penitentiary is located)) (15)

FRAME 16.

Locate grid square 4466 on your LEAVENWORTH map. What is the name of the church located in this grid square? ______________ ______________

(355576 (If you did not write this number correctly, turn back to frame 13 and review the steps)) (29)

FRAME 30.

Any scale or rule that divides the side of a grid square into tenths can be used to read 6-digit coordinates. Look at the plastic training aid provided with this text. Find the two L-shaped scales divided into tenths. These scales are used to read 6-digit ________________.

Set 2-2. RELATING POINT LOCATION TO THE MILITARY GRID REFERENCE SYSTEM

(bottom-up) (43)

FRAME 44. INFORMATION FRAME.

In the following frames, you will learn how your LEAVENWORTH map fits into the total military mapping program — the Military Grid Reference System. Using the knowledge of the Military Grid Reference System, you will then learn how to report your location on the LEAVENWORTH map to a distant headquarters or unit.

(Go on to next frame) (2)

FRAME 3.

Find the numbers for the grid lines on your LEAVENWORTH map. The line numbers are printed in the map margin and also in heavy, black type in the middle of the map itself. Reading from left to right, the eastings are numbered from _________ to 49.

(Flintlock Church) (16)

FRAME 17.

On your LEAVENWORTH map, what school is located in grid square 4155?

__________________.

421

(coordinates) (30)

FRAME 31.

Find grid square 3847 on your LEAVENWORTH map. Place the correct L-shaped scale of your plastic protractor exactly over the lines which form the grid square. Which of the two scales on the plastic protractor fits exactly?

a. 1:25,000 b. 1:50,000

(Go on to next frame) (44)

FRAME 45.

The standard Military Grid Reference System divides the earth into zones and tiers (see Panel 2-1). The zone reading "to the right" is in numbers, 1 to 60, and the tier reading "up" is in letters, A to Z (without the I and O). The combination of zone number and tier letter is called the GRID ZONE DESIGNATION. The grid reference box on the LEAVENWORTH map (center of bottom margin) explains the GRID ZONE DESIGNATION for the location of the map. What is the GRID ZONE DESIGNATION for the Leavenworth map?

a. 403622 b. UP c. 15S

432

(28) (3)

FRAME 4.

Reading up from the bottom of your LEAVENWORTH map in the right margin, what are the numbers of the northings?

a. 5 to 41 b. 46 to 73

(Eldorado) (17)

FRAME 18.

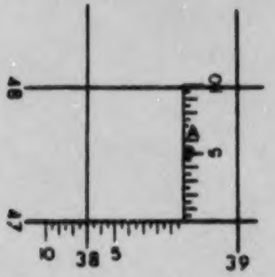
On your LEAVENWORTH map, what school is located in grid square 4550?

(b. 1:50,000) (31)

FRAME 32.

The sketch shows how to place the scale for the left-to-right reading at the imaginary line inside the grid square. Notice that point A is 7/10 of the distance from line 38 to 39. What are the first 3 digits of the grid coordinates (left-to-right reading)?

a. 381 b. 385 c. 387



(c. 15S (Numbers to the right (column 15) and letters up (ler S) (Panel 2-1)) (45)

FRAME 46.

The grid zones are further subdivided into 100,000-meter squares identified by two letters which are also read to the right and up (see panel 2-2). The grid reference box identifies the 100,000-meter square in which the LEAVENWORTH map falls as ____________________.

434

(b. 46 to 73) (4)

FRAME 5.

You always begin to locate points by beginning in the lower left corner. First, you read the eastings from left to right. For the northings, you read from the bottom ________________.

(Lanter School) (18)

FRAME 19.

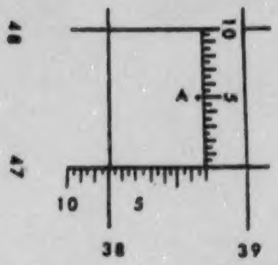
Four-digit grid coordinates locate a grid square. Six-digit coordinates pinpoint objects inside a grid square. For example, 3625 locates a square and 368254 locates a road junction inside that square. The number 8 is added as the third digit; the number 4 is added as the ________________ digit.

(c. 387) (32)

FRAME 33.

Point A is in the same location as before. The scale is placed correctly for the bottom-up reading (last 3 digits). What are the 6-digit coordinates?

a. 387471 b. 387475 c. 387477



(UP) (46)

FRAME 47.

The outline of each of these squares is an even 100,000-meter grid line with the numbers increasing to the right and up (Panel 2-2). The left easting of the marked square UP is 300,000 meters east. What is the right easting of that square?

a. 200,000 meters east b. 300,000 meters east c. 400,000 meters east (up) (5)

FRAME 6.

Every grid square has a 4-digit number, such as 3354. The first two digits (33) stand for the correct easting; the last two digits (54) stand for the correct ________________.

(6th) (19)

FRAME 20.

The 4-digit grid coordinates 4659 locate Platte City on your LEAVENWORTH map. The 6-digit coordinates 468597 pinpoint a cemetery in the outskirts of the town. Compare 4659 and 468597. The 46 and 59 for the grid square are still in the 6-digit coordinates. Which digits have been added?

a. 1st and 4th b. 2d and 5th c. 3d and 6th

(b. 387475) (33)

FRAME 34.

Now practice what you have learned by using the plastic scale to locate points on your LEAVENWORTH map. Find grid square 4550, in which Lanter School is located. What are the 6-digit coordinates which locate Lanter School?

a. 451507 b. 455505 c. 457501

(c. 400,000 meters east (The LEAVENWORTH map falls in the 100,000-meter square designated by the letters UP and outlined by the 300,000 and 400,000 meters east lines and 4,300,000 and 4,400,000 meters north lines)) (47)

FRAME 48.

The grid line numbers $^{3}28\ ^{000\text{m}}$E and $^{43}47\ ^{000\text{m}}$N, in the lower left corner of your LEAVENWORTH map refer to 328,000 meters east and 4,347,000 meters north, respectively. These are the grid coordinates for the first grid lines in the ____________ ____________ corner of the map.

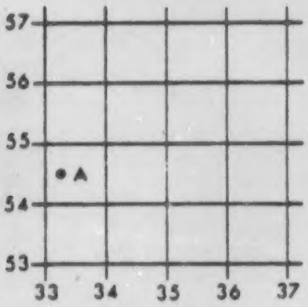
428

(northing) (6)

FRAME 7.

Every grid square number comes from the two grid lines which cross at the lower left corner of the square. Point A in the figure below is in grid square 3354. In writing the grid square number, the number of which line is written first?

a. easting b. northing



(c. 3d and 6th) (20)

FRAME 21.

The 4-digit coordinates locate the grid square. The 6-digit coordinates locate not only the grid squares but a point within the square. In the coordinates 469595, which 2 digits locate the point within the square? ____________ and ____________

439

(c. 457501 (If your answer was 451507, you reversed the 3d and 6th digits)) (34)

FRAME 35.

On your LEAVENWORTH map, Flintlock Church is in grid square 4466. What is its 6-digit location? ____________

(lower left (southwest) (The coordinates are given in full in the southwest corner of military maps)) (48)

FRAME 49.

On all other grid lines, the $^{000\text{m}}$E or $^{000\text{m}}$N are not shown on the map, but are understood. The ^{3}48 in the lower right corner means __________ meters east.

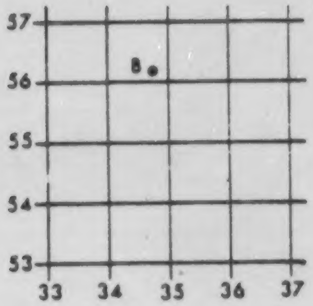
410

(a. easting) (7)

FRAME 8.

Determine the correct number for the grid square containing point B. Start from the lower left. The easting which goes through the lower left corner of the square is 34. Now, find the northing that goes through the lower left corner. What is the 4-digit number?

a. 3355 b. 3456 c. 3557



(3d and 6th (9,5)) (21)

FRAME 22.

The first 3 digits of 6-digit coordinates are the easting grid reading and the last 3 digits are the ________________ grid reading of the more accurate location.

(444662) (35)

FRAME 36.

Using the plastic coordinate scale find the point at 360706 on the LEAVENWORTH map. What ground feature is located there?

a. cemetery b. road junction c. lake

(348,000) (49)

FRAME 50. INFORMATION FRAME.

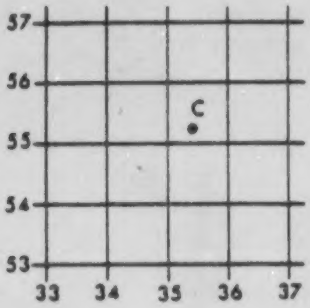
When reporting your location (Hazelwood School 403622, LEAVENWORTH map) to another unit or headquarters which is outside your 100,000-meter square or in another grid zone, or both, certain procedures are necessary to properly identify your position.

412

(b. 3456) (8)

FRAME 9.

Remember that the grid square is identified by the eastings (vertical grid lines) and northings (horizontal grid lines) which form the lower left corner of the square. You write the number of the easting first, then the northing. The number for the grid square containing point C is __________________.



(northing) (22)

FRAME 23.

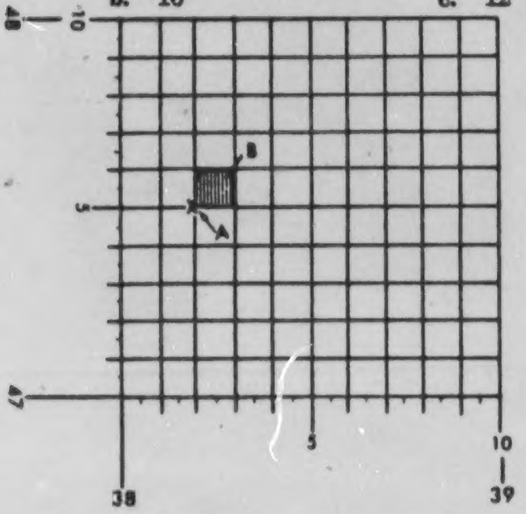
You have learned that grid coordinates with 4 digits locate a grid square. The number 4659 located Platte City on your LEAVENWORTH map. Six-digit coordinates are, as you have seen, more accurate. The two additional numbers (digits) locate a point within the __________________ square.

(c. lake) (36)

FRAME 37.

The 4-digit coordinates locate grid square 3847. The number 382475 locates one of 100 imaginary squares at point A. If the grid were divided into 10,000 imaginary squares, how many digits would be required to pinpoint B?

a. 8 b. 10 c. 12



(Go on to next frame) (50)

FRAME 51.

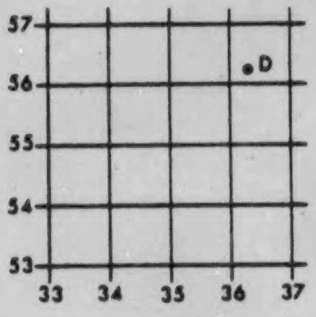
When the unit to which you are reporting your location (Hazelwood School 403622) is in the same 100,000-meter square, you report your location simply by stating the coordinates. You would report your location as __________________.

414

(3555 (35 is the vertical grid line, 55 is the horizontal grid line)) (9)

FRAME 10.

Find the number of grid square in which D is located. It is in square ____________________.

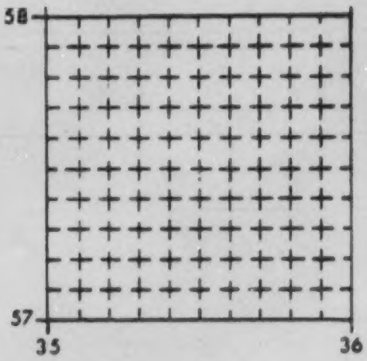


(grid) (23)

FRAME 24.

For 6-digit coordinates, the sides of the grid square are divided into tenths with imaginary lines (shown as dotted lines here). These form 100 imaginary smaller squares. What would be the 4-digit coordinates for the grid square shown below?

a. 3557 **b. 3657** **c. 5735**

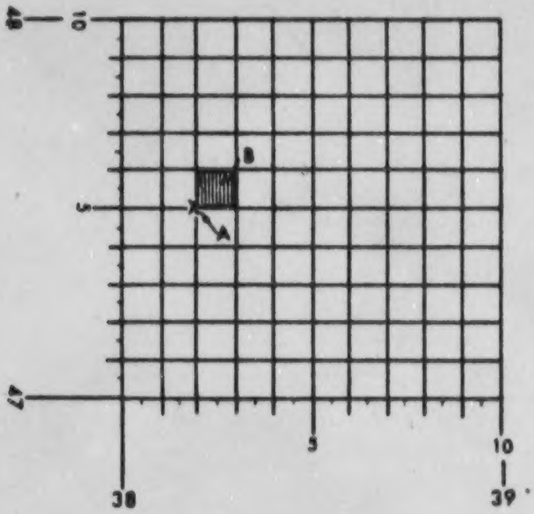


(a. 8) (37)

FRAME 38.

The 6-digit number for point A was 382475. The 8-digit coordinates for point B are 38274757. Which digits were added?

a. 1st and 8th b. 3d and 6th c. 4th and 8th



(403622) (51)

FRAME 52.

In reporting your location to a unit or headquarters outside your UP 100,000-meter square but in the same grid zone, the 6-digit grid coordinates alone could refer to any one of several points in other 100,000-meter squares. To avoid misidentification, you identify your square by placing the letters ______________ preceding the coordinates.

436

(3656) (10)

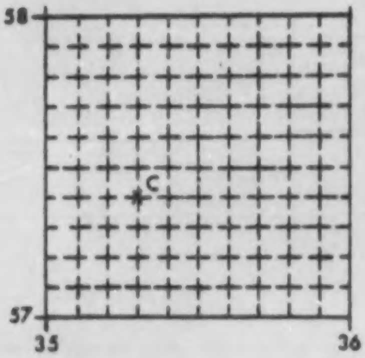
FRAME 11.

The square, you have seen, has each time been identified by giving the number of the easting first, then the northing. In grid square 3556, 35 would be the easting and 56 the ________________.

(a. 3557 — lower left corner, easting (vertical) first) (24)

FRAME 25.

In grid square 3557, the 6-digit coordinates for point C are 353574. The third digit means that point C is 3/10 of the distance from easting 35 to easting 36. The sixth digit means that point C is 4/10 of the distance from northing 57 to northing ________________.



417

(c. 4th and 8th) (38)

FRAME 39.

No matter how many digits are used, the first half of the coordinate numbers locates the easting (left-to-right). The last half locates the northing (bottom-up). The total number of digits in any set of coordinates is always ________________.

a. odd b. even

(UP) (52)

FRAME 53.

In reporting your location in Hazelwood School to a headquarters outside your 100,000-meter square, but in the same zone, you would state your location to be ____________________.

118

(northing) (11)

FRAME 12.

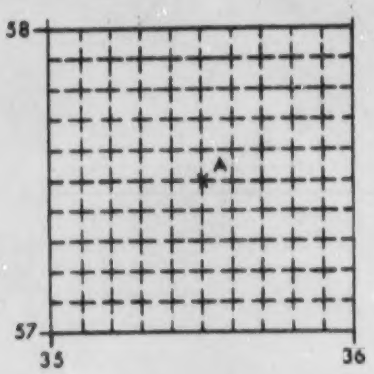
Grid square numbers are called grid coordinates. In writing grid coordinates, you write the number of the easting first and the number of the __________ next.

---

(58) (25)

FRAME 26.

Note that point A is in the center of grid square 3557. That is, A is 5/10 of the distance from easting 35 to easting 36 and from northing 57 to northing 58. The 6-digit coordinates would be 35 ________ 57 ________.



(b. even) (39)

FRAME 40.

The 6-digit coordinates locate points within 100 meters of their actual ground location on the LEAVENWORTH map. The 8-digit coordinates further divide each 100 meters into 10-meter units. What is the accuracy of the 8-digit coordinates?

a. 10 meters b. 20 meters c. 50 meters

(UP403622 (See grid reference box once again)) (53)

FRAME 54.

Hazelwood School, the sample point in the grid reference box, can be located in the 100,000-meter square in two ways: either by 340,300 meters east by 4,362,200 meters north or by the letters and grid coordinates ________________.

(northing) (12)

FRAME 13.

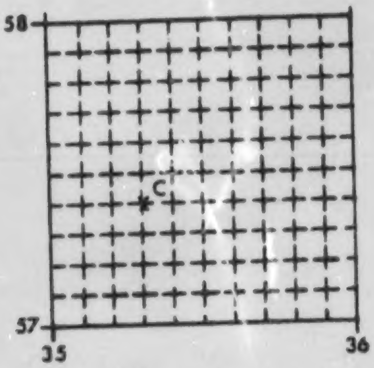
The numbers of the eastings and northings which identify a grid square are called the grid ________________.

(355575) (26)

FRAME 27.

You learned that point C was on imaginary easting 353. The last 3 numbers in 6-digit coordinates locate the imaginary northing. What would be the correct 6-digit coordinates for point C?

a. 353572
b. 353574
c. 353576



(10 meters) (40)

FRAME 41.

The 8-digit coordinates locate points to within 10 meters on the ground, which is closer than average user requirements and map accuracy warrants. The center of Terminal Bridge on your LEAVENWORTH map is 35655351. This number should locate the point to within ______________ meters of the exact center of the bridge.

(UP403622 (This is the shorter way of referring to the coordinates in the correct 100,000-meter square)) (54)

FRAME 55.

Now let us assume that you must report your location (Hazelwood School) to higher headquarters, which is not only outside your 100,000-meter square but also in another grid zone. In this case you would have to include the grid zone designation, the 100,000-meter square identification, and the coordinates of Hazelwood School. Therefore, in reporting your location to this higher headquarters you would state your location as ____________________.

(coordinates) (13)

FRAME 14.

Practice with the LEAVENWORTH map. Find Terminal Bridge, which crosses the Missouri River near the center of the city of Leavenworth. What are the grid coordinates of the square in which Terminal Bridge is located?

a. 3553 b. 5335

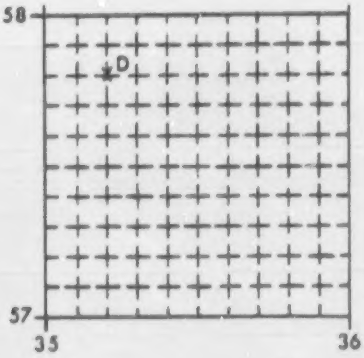
Turn back to bottom of page 2-1 for frame 15

(b. 353574 (Point C is 4/10 of the distance up from line 57)) (27)

FRAME 28.

You combine the 3-digit "right" reading with the 3-digit "up" reading for 6-digit coordinates. What are the 6-digit grid coordinates of point D?

a. 352578 b. 353574 c. 358572



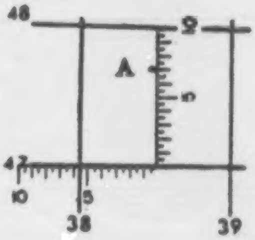
Turn back to top of page 2-8 for frame 29

(10) (41)

FRAME 42.

You must estimate the position of the point between divisions on your coordinate scale to determine the 4th and 8th digits. For the left-to-right reading to locate point A, you know that the first three numbers are 385. Point A is halfway (5/10) between the 500- and 600-meter division. What would the first four numbers be?

a. 3850 b. 3855 c. 3857



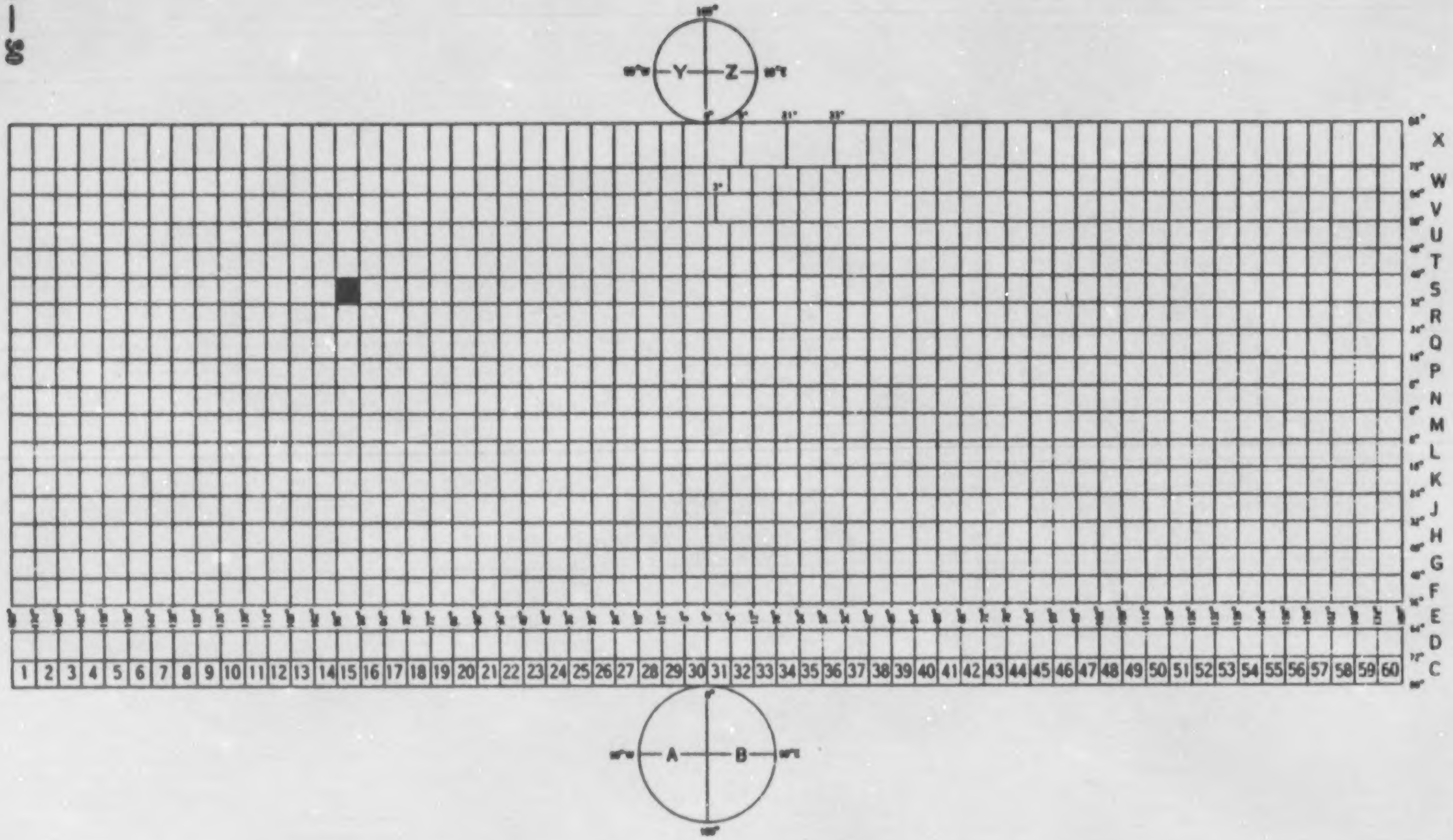
Turn back to bottom of page 2-2 for frame 43

(15SUP403622) (55)

FRAME 56. REVIEW FRAME.

To review, the military grid system applies to the entire world and is divided into grid zones, further divided into 100,000-meter squares. The LEAVENWORTH map is in Grid Zone 15, Tier S, and in 100,000-meter square UP. See Panels 2-3 and 2-4.

PANEL 2-1


Y
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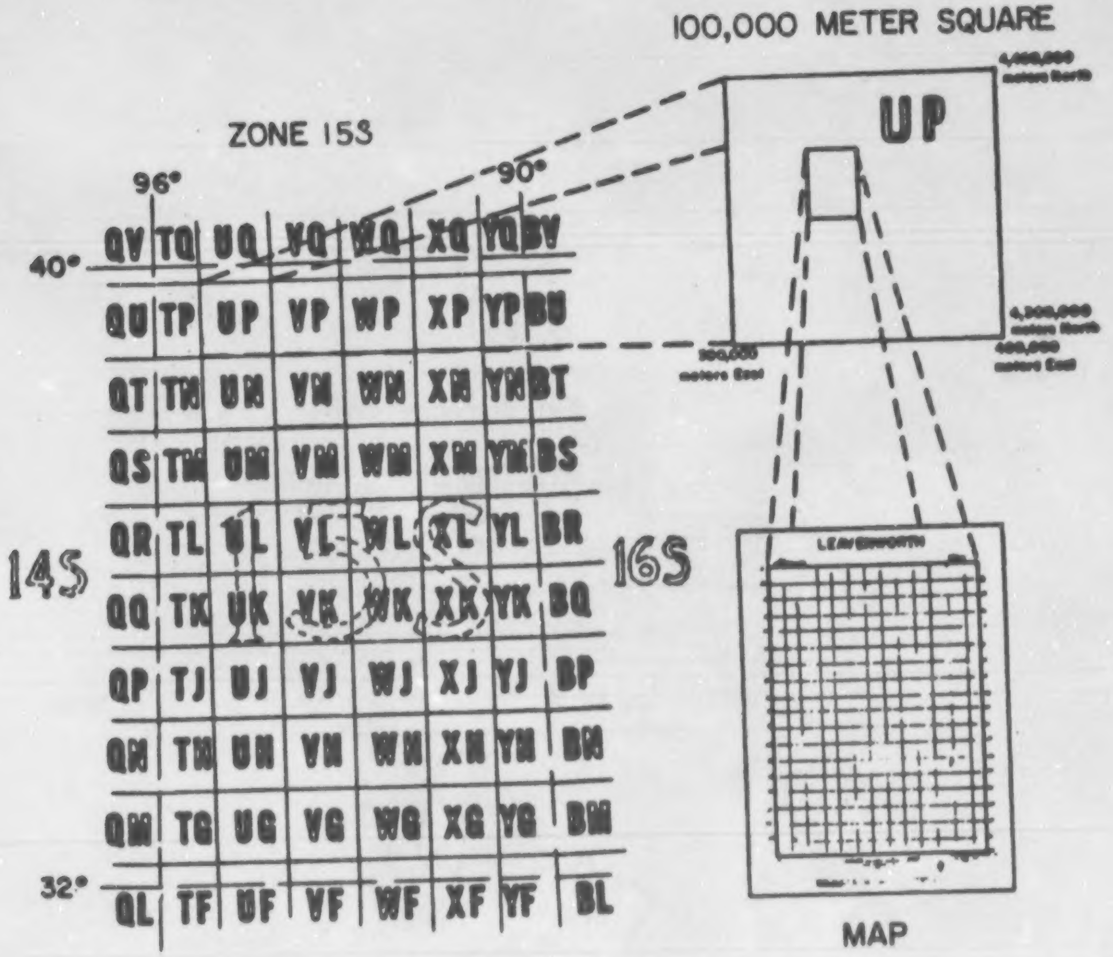
58
59
60
A
B

Military Grid Reference System, (Fort Leavenworth map is within grid zone designation 15S.) (Black square).

445

PANEL 2-2

MAP LOCATION WITHIN GRID ZONE

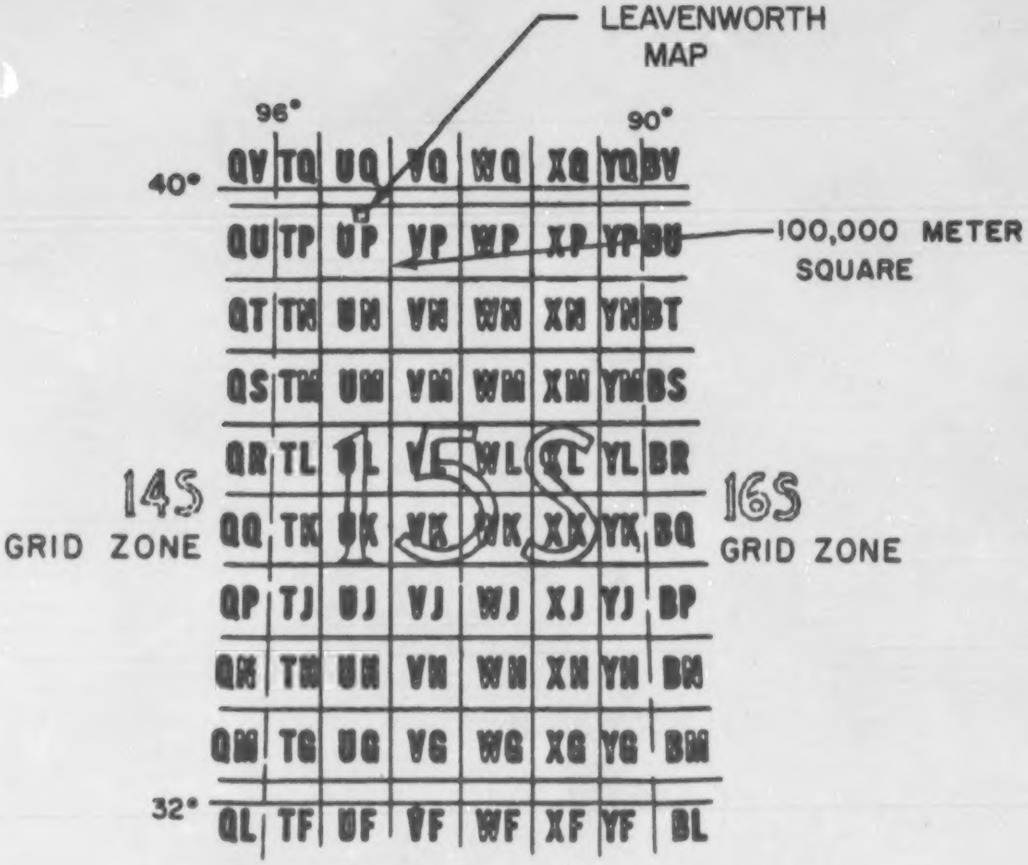

100,000 METER SQUARE
UP
4,400,000 meters North
4,300,000 meters North
300,000 meters East
400,000 meters East
ZONE 15S
96°
90°
40°
32°
QV TQ UQ VQ WQ XQ YQ BV
QU TP UP VP WP XP YP BU
QT TN UN VN WN XN YN BT
QS TM UM VM WM XM YM BS
QR TL UL VL WL XL YL BR
QQ TK UK VK WK XK YK BQ
QP TJ UJ VJ WJ XJ YJ BP
QN TH UH VH WH XH YH BN
QM TG UG VG WG XG YG BM
QL TF UF VF WF XF YF BL
14S
16S
LEAVENWORTH
MAP

457

446

PANEL 2-3

MAP LOCATION WITHIN GRID ZONE (LEAVENWORTH MAP SHOWN IN UP 100,000-METER SQUARE)


LEAVENWORTH MAP
96°
90°
40°
32°
100,000 METER SQUARE
14S
GRID ZONE
15S
16S
GRID ZONE

QV	TQ	UQ	VQ	WQ	XQ	YQ	BV
QU	TP	UP	VP	WP	XP	YP	BU
QT	TN	UN	VN	WN	XN	YN	BT
QS	TM	UM	VM	WM	XM	YM	BS
QR	TL	UL	VL	WL	XL	YL	BR
QQ	TK	UK	VK	WK	XK	YK	BQ
QP	TJ	UJ	VJ	WJ	XJ	YJ	BP
QN	TH	UH	VH	WH	XH	YH	BN
QM	TG	UG	VG	WG	XG	YG	BM
QL	TF	UF	VF	WF	XF	YF	BL

GRID ZONE DESIGNATION

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PANEL 2-4

SUMMARY OF MILITARY GRID REFERENCE SYSTEM

a. Military Grid Reference System.

You have seen that a Military Grid Reference System applies to the entire world.

b. Grid Zones.

The system is composed of vertical columns or grid zones identified by numbers, and horizontal tiers, identified by letters. The combination of numbers and letters, for example 18M, 15S, etc., is called the Grid Zone Designation.

c. 100,000-Meter Square Identification.

Each grid zone is, in turn, divided into 100,000-meter squares, identified by pairs of letters, such as TP, UP, VP, etc.

d. Map Areas.

The area of the Fort Leavenworth map is approximately 21,000 meters East-West by 27,000 meters North-South. A map mey fall entirely within one 100,000-meter square, or it may contain portions of more than one 100,000-meter square. The grid reference box in the lower margin of each map sheet tells you the correct 100,000 meter identification for that sheet, and the correct grid zone designation.

PART III

DISTANCE

Set 3-1. DETERMINING GROUND DISTANCE BY REPRESENTATIVE FRACTIONS (RF)

FRAME 1.

Any specific distance on a map represents a specific distance on the ground. For example, 1 inch on your LEAVENWORTH map (map distance) equals 50,000 inches on the ground (ground distance). The relation of these two distances is called the map's scale or representative fraction (RF). The scale of a map is the relation between map distance and ______________ distance.

Set 3-2. SCALES OF MILITARY MAPS

(a. 2.5. 250,000 centimeters equals 2,500 meters or 2.5 km. 250,000 cm ÷ 100,000 cm per kilometer = 2.5 kilometers.) (8)

FRAME 9.

In previous frames, you have learned the purpose and use of map scale. Military maps are classified according to scale as follows:

small — $\frac{1}{600,000}$ or smaller

medium — between $\frac{1}{75,000}$ and $\frac{1}{600,000}$

large — $\frac{1}{75,000}$ or larger

The military map of a scale $\frac{1}{600,000}$ or smaller is classified as ______________ ______________.

(tick marks) (16)

FRAME 17.

To determine the distance in miles (and tenths), you move down to the bar scale marked in ________________.

(c. 5900. The distance (on the bar scale) measures about 1970 yards, and converts (3 × 1970) to about 5900 feet.) (24)

FRAME 25.

You often have to measure the length of curving section of road. To do this, you "straighten out" the curve by ticking off short straight segments in sequence on the edge of a sheet of paper (Panel 3-7). The equivalent straight line distance of the curve can now be measured on the bar scale. For example, a sharp curve will require which type of adjustment?

a. shorter segments b. longer segments c. varied lengths of segments

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(ground) (1)

FRAME 2.

The map scale or RF may be written as a ratio, 1:50,000, or as a fraction, $\frac{1 \text{ (map)}}{50{,}000 \text{ (ground)}}$. Both mean the same thing. How is the scale written in the marginal information of the Leavenworth map?

a. 1:50,000

b. $\frac{1}{50{,}000}$

(small scale) (9)

FRAME 10.

The larger the denominator of the RF, the smaller will be the scale. Why? Because $\frac{1}{600{,}000}$ is a smaller value than $\frac{1}{75{,}000}$, just as ⅛ of a pie is a smaller piece than ¼ or ½. Which of the RF's is the smallest scale?

a. $\frac{1}{25{,}000}$,

b. $\frac{1}{50{,}000}$

c. $\frac{1}{100{,}000}$

(miles) (17)

FRAME 18.

However, you see that the distance between the two ticks is longer than the bar scale. Therefore, place this right tick on the right end of the scale (at the 3-mile point). Mark the left end of the bar scale (marked with a 1) on the paper's edge. You have now marked ________ miles of the distance.

(a. shorter segments. Each segment should stay within the road limits. A too long segment will result in a too short distance.) (25)

FRAME 26.

On your LEAVENWORTH map locate the junction of routes 45 and 92 (388588). Route 45 curves from this point until it reaches the north-south road out of Weston (364652). Using the curved-road measuring technique, what is the measured road distance, in kilometers?

a. 6.0 b. 7.2 c. 8.3

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(a. 1:50,000. Other maps may use the fraction.) (2)

FRAME 3.

If a map were drawn with a scale of 1:2000, how many inches on the ground would 2 inches on the map represent? On a map of the same scale, how many centimeters on the ground would 2 centimeters on the map represent?

Inches: a. 1000 b. 2000 c. 4000

Centimeters: a. 1000 b. 2000 c. 4000

(c. $\frac{1}{100{,}000}$. This is the smallest fraction in the group) (10)

FRAME 11.

You learned that 5 centimeters of a map distance equals 2.5 km of ground distance at a scale of $\frac{1}{50{,}000}$ (large-scale). If you measured 5 centimeters (map distance) between two towns on a small-scale map of $\frac{1}{1{,}000{,}000}$, what would be the ground distance in kilometers?

a. 25 b. 50 c. 75

(4) (18)

FRAME 19.

Next slide this new mark to the right until it falls on the mile graduation that permits the original left tick to fall within the tenths of a mile scale. Read the value. It will be ________ miles.

Set 3-4. DETERMINING UNKNOWN SCALE OF MAP OR PHOTO

(c. 8.3) (26)

FRAME 27.

You may find maps, sketches, or photographs whose scale is unknown. You can determine the scale if you can identify objects or features with known measurable distances. For example, your map of unknown scale shows a church located close to a crossroad near your unit. The map distance is ½ inch. You then measure the actual ground distance between the crossroads and church and find it to be 100 yards (3600 inches). Therefore, ½ inch map distance equals 3600 inches ground distance. What is the RF of the map?

a. $\frac{1}{3600}$ b. $\frac{1}{7200}$ c. $\frac{1}{12,500}$

(c. 4000 inches, 4000 centimeters) (3)

FRAME 4.

You notice that inches or centimeters on the map represent inches or centimeters on the ground. Sometimes map readers make the mistake of using one measure for map distance (centimeters or inches) and a different measure for ground distance (meters or yards). Panel 3-1 tells you how to convert from one unit to another. If a map distance is measured in centimeters, the ground distance will be measured in ________________.

a. kilometers b. meters c. centimeters

(b. 50. 5cm × 1,000,000 = 5,000,000cm = 50,000 meters = 50 km.) (11)

FRAME 12.

The standard Army map scales are:

small — $\frac{1}{1,000,000}$

medium — $\frac{1}{250,000}$

large — $\frac{1}{50,000}$

What scale would be used mostly for strategic studies (covering large areas) by commanders of large units?

a. small b. medium c. large

(2.2) (19)

FRAME 20.

The distance (from Iatan to Weston) required is the sum of the 4 miles you first ticked off and the reading from the last frame (2.2 miles). The distance along the railroad between the two locations is __________.

(b. $\frac{1}{7200}$. RF $= \frac{\text{MD}}{\text{GD}} = \frac{\text{½ inch}}{\text{3600 inches}}$ or RF $= \frac{1}{7200}$) (27)

FRAME 28.

$\frac{\text{Map distance}}{\text{Ground distance}}$, measured in the same units, will always give you the ____________________ of a map or photo.

(c. centimeters) (4)

FRAME 5.

RF stands for a fraction or $\frac{\text{map distance}}{\text{ground distance}}$ or $\frac{\text{MD}}{\text{GD}}$ (see Panel 3-2). Thus, $\text{RF} = \frac{\text{MD}}{\text{GD}} = \frac{\text{1 centimeter}}{\text{50,000 centimeters}}$ or $\frac{\text{1 inch}}{\text{50,000 inches}}$. Both distances must be in the same units of measurement. Which of the following is correctly written for a map scale of 1:25,000?

a. $\text{RF} = \frac{1}{25{,}000}$ b. $\text{RF} = \frac{\text{1 in}}{\text{25,000 ft}}$ c. $\text{RF} = \frac{\text{1 in}}{\text{25,000 yds}}$

Set 3-3. DETERMINING GROUND DISTANCE BY BAR SCALE

(a. small. The small-scale map $\left(\frac{1}{1{,}000{,}000}\right)$ would cover the largest area of ground on each map sheet.) (12)

FRAME 13.

Bar scales (see Panel 3-4) are printed on military maps to provide another way to determine ground distances from the map information. The **bar scale** is the ruler, graduated in miles, meters, and yards, which appears in the bottom margin. The bar scale shows how much ground distance is represented by certain lengths of map distance. How many meters of ground distance does the complete meter scale represent?

a. 4000 b. 5000 c. 6000

(6.2) (20)

FRAME 21.

For even longer distances in miles, you would first tick mark as many 4-mile steps as possible on the edge of your paper. Then, to measure the additional distance to tenths of a mile, you would as before, slide your paper to the right to the mile mark on the bar scale (0, 1, 2, 3) which causes the remaining distance to be measured to fall within the __________ of a mile divisions of the bar scale. Panel 3-6 tells you how to determine distances to points that fall outside your map sheet.

(Scale) (28)

FRAME 29.

You can also determine the scale of a map or photograph of unknown scale by comparing it with a map of the same area whose scale is known. Remember the $\frac{1}{50,000}$ scale map where the map distance between two road intersections was 5 centimeters? The actual ground distance between the two intersections would be 5cm × 50,000 or 250,000cm. If you locate the same road intersections on the map of unknown scale and find them to be 20cm apart, you can use the ground distance obtained from the $\frac{1}{50,000}$ scale map in the scale formula $\frac{MD}{GD} = RF$ to find the scale of the unknown map. What do you determine this RF to be?

a. $\frac{1}{12,500}$ b. $\frac{1}{25,000}$ c. $\frac{1}{200,000}$

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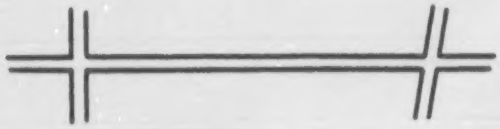
(a. $RF = \frac{1}{25,000}$. In using RF's, remember that the units must be the same.) (5)

FRAME 6.

In using the scale or RF to find the ground distance (GD), you first measure the map distance (MD). The sketch shows two road junctions as they appear on a map. If your protractor has a centimeter scale, use it to measure the distance. If you do not have a centimeter scale, Panel 3-3 tells you how to use your map to obtain centimeter measurements. What is the map distance, in centimeters, between the road junctions?

a. 3 b. 4 c. 5



(c. 6000. The zero of the bar scale is not at the left end. From the zero, there are 5000 meters (graduated in 1000-meter units) to the right, and another 1000 meters (graduated in 100-meter units) to the left. The combined length is 6000 meters.) (13)

FRAME 14.

You normally use the bar scale by "taking the measured map distance to the scale". One good way is to tick mark the map distance on the edge of a sheet of paper. The measurement is moved and placed so that the right end (tick) falls on an even reading and the left end (tick) falls in the subdivided section to the left of the zero. The map distance shown in Panel 3-5 equals how many meters of ground distance?

a. 1300 b. 1405 c. 1520

(10ths) (21)

FRAME 22.

The bar scales are handy rulers which help you to convert map measurements to actual ground distance. Remember to use the bar scale which gives you the desired units of ground measurement. If you want a ground distance in kilometers, you would use the meters scale in the map margin (1000 meters = 1 kilometer). Measure one side of a grid square on your LEAVENWORTH map and take it to the meters bar scale. How long in meters, is the side of a grid square?

a. 500 b. 1000 c. 1500

$\left(a.\ \frac{1}{12{,}500}.\ \frac{MD}{GD} = \frac{20cm}{250{,}000cm} = \frac{1}{12{,}500}\right)$ (29)

FRAME 30.

The two steps of finding the ground distance and using the scale formula $\left(RF = \frac{MD}{GD}\right)$ can be combined into one as follows:

Use the measured distance on the map of unknown scale (UMD) as the numerator, and the measured distance on the map of known scale (KMD) as the denominator, and multiply this fraction by the RF of the known map: $\frac{UMD}{KMD}$ (RF). Using this formula, find the RF of a map of unknown scale on which the distance between two points is measured as 2 inches, if the same distance on a 1:50,000 scale map is measured as 4 inches.

471

(c. 5) (6)

FRAME 7.

You have measured the map distance as 5 centimeters. If the map scale is 1:50,000, then the ground distance is 50,000 times as long as the map distance. What is the ground distance, in centimeters, between the road junctions?

a. 2,500 b. 25,000 c. 250,000

(c. 1520. The right tick is placed on an even meter mark (1000 in this case) and the left end is among the subdivided section (in 100 meters). The total distance is 1520 meters.) (14)

FRAME 15.

Use your map scale (1:50,000 on your Protractor and Map Scales) to locate the road junctions at 404638 and 405678 on your LEAVENWORTH map. Using the tick mark method explained in the previous frame, what is the distance, in yards, between the two junctions?

a. 4400 b. 5500 c. 6600

(b. 1000. The grid squares on large-scale military maps are all drawn 1000 meters square.) (22)

FRAME 23.

The grid squares on the LEAVENWORTH map are 1000 meters, or 1 kilometer, long. You can estimate distance quickly using the 1 kilometer squares as "measuring sticks". What is the approximate straight line distance, in kilometers, from Horseshoe Lake (4247) to Roberts Lake (4556) ?

a. 3 b. 5 c. 10

Set 3-5. DISTANCE AND TRAVEL TIME

$$\left(\frac{1}{100{,}000},\ \frac{\text{UMD}}{\text{KMD}}\ (\text{RF}) = \frac{2''}{4''} \times \frac{1}{50{,}000} = \frac{2''}{200{,}000''} = \frac{1}{100{,}000}\right)\ (30)$$

FRAME 31.

You often have to find the time it will take you to travel to a new location. How long it will take you depends on the ground distance (D) to the new location and how fast you travel (r). So, ground distance and rate of ________________ are the two factors you must know.

462

(c. 250,000. The map distance is 5 centimeters and the ground distance is 50,000 times that or 250,000 centimeters. Watch the units in this multiplication.) (7)

FRAME 8.

The ground distance between the intersections is 250,000 centimeters, but is usually given as meters or kilometers. Therefore, you convert the centimeters to the desired unit. To convert centimeters to meters, divide by 100; to convert centimeters to kilometers, divide by 100,000. What is the ground distance, in kilometers, between the road intersections?

a. 2.5 b. 25 c. 50

Turn back to bottom of page 3-1 for frame 9

(a. 4400. Place the right end tick on the 4000 *yard* mark of the bar scale and the left end tick will fall on the 400 mark to the left of zero (4000 + 400 = 4400)) (15)

FRAME 16.

To measure longer distances, the same procedure is used, but the measurement is made in steps. You have to determine the distance along the railroad from the road crossing at Iatan (293711) to the road crossing below Weston (361637). You will again use __________ __________ along the edge of the paper to mark the distance between these two locations.

Turn back to top of page 3-2 for frame 17

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(c. 10. You can count ten 1-km squares between the two lakes.) (23)

FRAME 24.

Airport runway lengths are often given in feet. You make the measurement using the YARDS bar scale and convert the distance to feet. (3 feet = 1 yard) On the LEAVENWORTH map, what is the length, in feet, of the longer runway at Sherman Air Force Base?

a. 5000 b. 5400 c. 5900

Turn back to bottom of page 3-2 for frame 25

(speed or movement) (31)

FRAME 32.

In order to find the time it will take you to travel a certain distance, you **divide** the ground **distance** by the **rate of movement.** So if you have to travel 10 miles and you move at the rate of 5 miles per hour, you would **divide** 10 by ________ to get the time required to go the 10 miles. You find the time to be ________ hours.

475

(5, 2) (32)

FRAME 33. INFORMATION FRAME.

In the same way, you can find the total distance (D) traveled in a given time if you multiply the rate of speed (r) and the time (t). You can also find the rate of speed (r) by dividing the total distance (D) by the time (t). If you know any two factors, you can find the third. The three formulas are:

1. To find distance: $D = rt$
2. To find speed: $r = \frac{D}{t}$
3. To find time: $t = \frac{D}{r}$

END OF FRAMES FOR PART III

PANEL 3-1

CONVERSION FACTORS

ONE	INCHES	FEET	YARDS	STATUTE MILES	CM	M	KM
INCH	1.0	0.0833	0.0277	-------	2.54	0.0254	-------
FOOT	12.0	1.0	0.333	-------	30.48	0.3043	0.0003
YARD	36.0	3.0	1.0	0.00056	91.44	0.9144	0.0009
STATUTE MILE	63360.0	5280.0	1760.0	1.0	160930.0	1609.0	1.6093
CENTIMETER	0.3937	0.0328	0.0109	-------	1.0	0.01	-------
METER	39.37	3.2808	1.0936	0.0006	100.0	1.0	0.001
KILOMETER	39370.0	3281.0	1094.0	0.6214	100000.0	1000.0	1.0

To convert a measurement from a unit shown in the 1st column to any other unit shown in table, multiply by the factor shown in column under desired unit.

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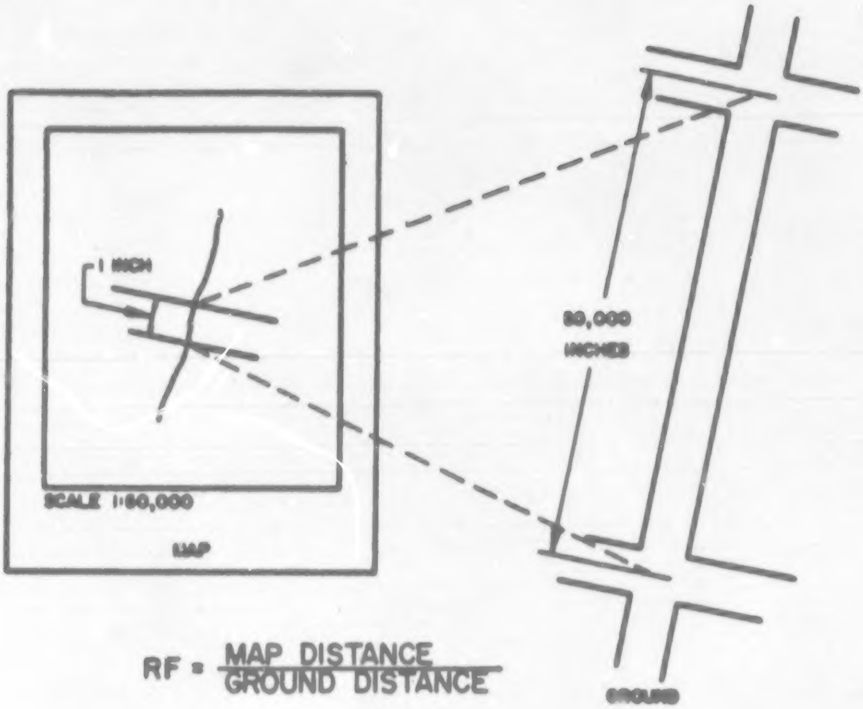
PANEL 3-2


1 INCH
SCALE 1:50,000
MAP
50,000
INCHES
GROUND

$$RF = \frac{\text{MAP DISTANCE}}{\text{GROUND DISTANCE}}$$

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PANEL 3-3

USING YOUR 1:50,000 SCALE MAP TO MEASURE CENTIMETERS

If you need to measure map or photograph distances in centimeters, but do not have a centimeter scale, you can make use of the following standard relationships on your map to obtain the needed measurements.

a. The grid lines on your 1:50,000 scale map are spaced exactly 2 centimeters apart, because they represent 1000 meters ground distance at 1:50,000 scale. A linear distance may be measured along any grid line, either horizontal or vertical. The grid lines perpendicular to this line cross it at 2-cm intervals.

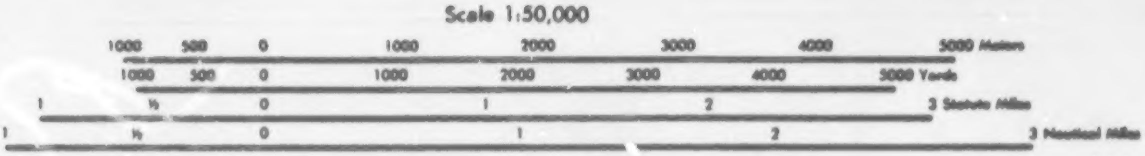
b. The 1000-meter divisions of the primary part of the meters bar scale in the map margin are spaced 2 cm apart, since they also represent 1000 meters at 1:50,000 scale.

c. For small measurements, less than 2 cm in length, the extension scale to the left of the zero on the meters bar scale is divided into 100-meter segments, each of which is .2 cm long.

d. For greater precision, the 1:50,000 grid coordinate scale on your protractor, also 2 cm on each side, is divided into tenths of a centimeter (10 millimeters).

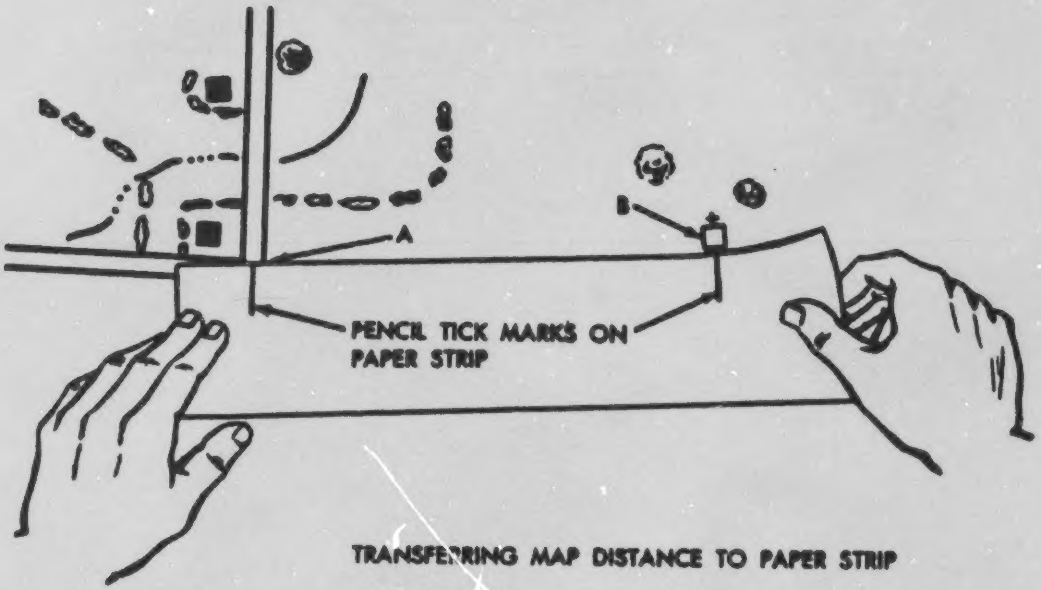
PANEL 3-4

BAR SCALES

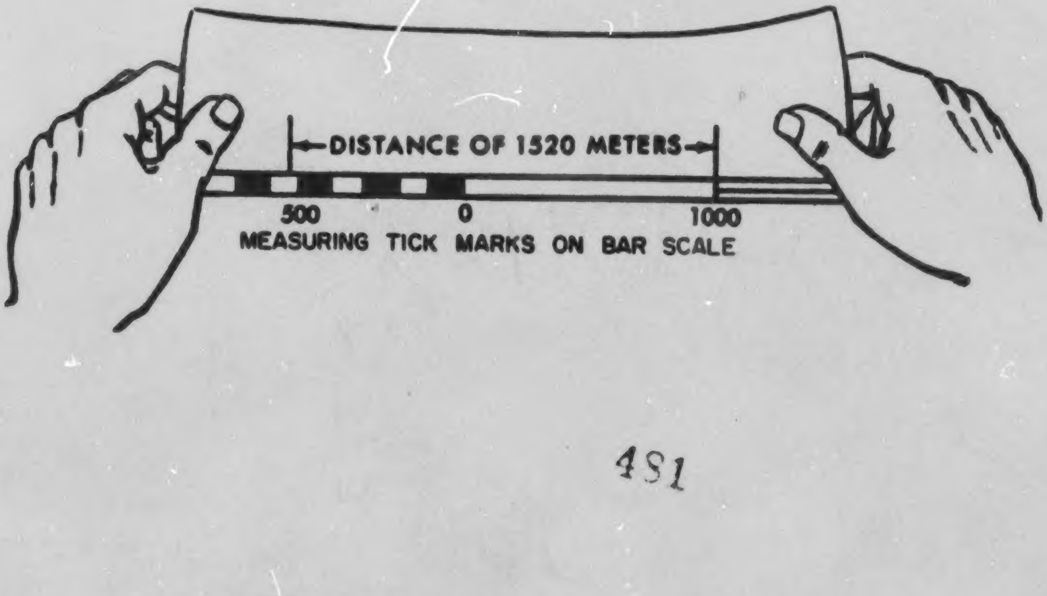

Scale 1:50,000
1000 500 0 1000 2000 3000 4000 5000 Meters
1000 500 0 1000 2000 3000 4000 5000 Yards
1 ½ 0 1 2 3 Statute Miles
1 ½ 0 1 2 3 Nautical Miles

PANEL 3-5

TAKING MEASURED MAP DISTANCE TO THE SCALE


A
B
PENCIL TICK MARKS ON PAPER STRIP

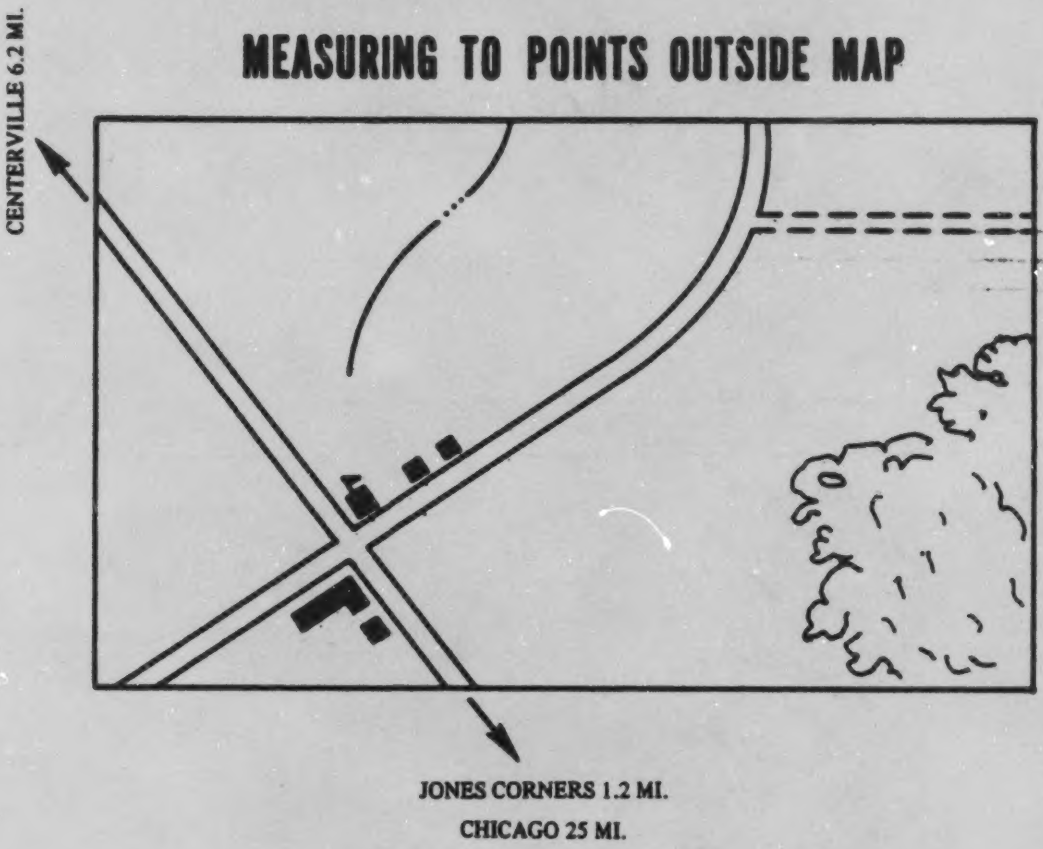
TRANSFERRING MAP DISTANCE TO PAPER STRIP


DISTANCE OF 1520 METERS
500
0
1000

MEASURING TICK MARKS ON BAR SCALE

PANEL 3-6

MEASURING TO POINTS OUTSIDE MAP


CENTERVILLE 6.2 MI.
JONES CORNERS 1.2 MI.
CHICAGO 25 MI.

Distances shown outside map margin represent distance from edge of map to destination or destinations indicated. Add this distance to measured map distance to find total distance to destination outside map.

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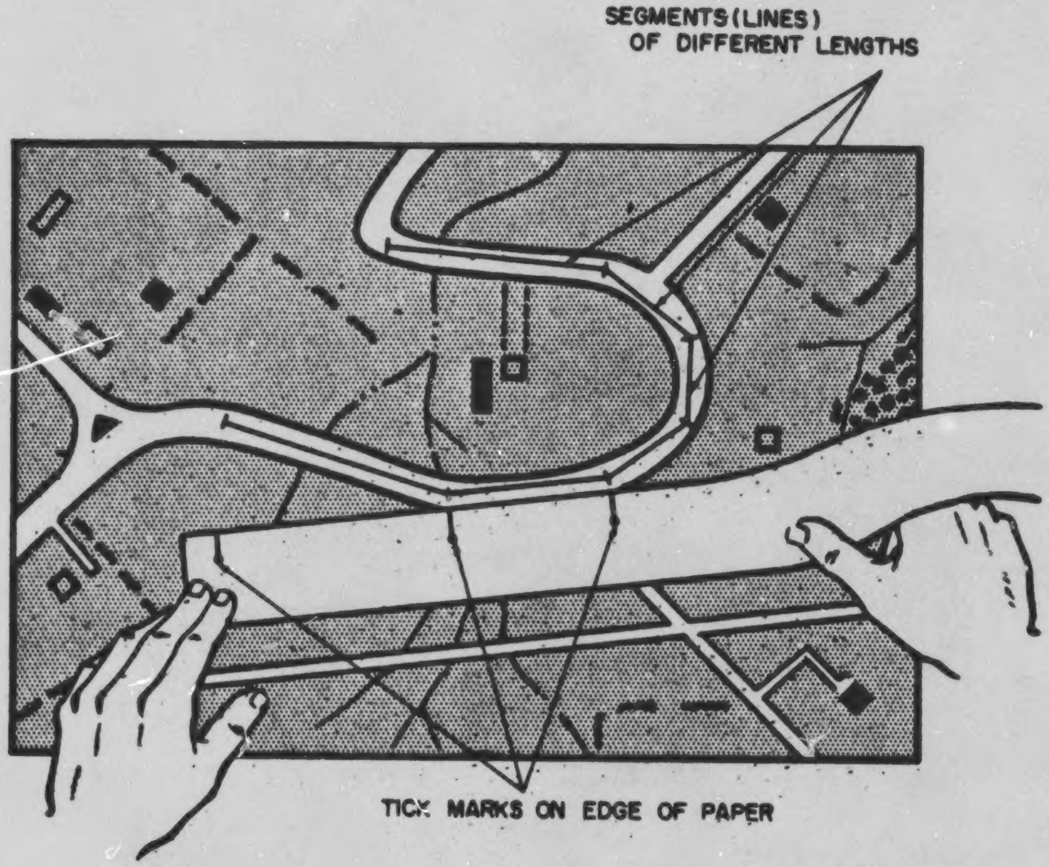
PANEL 3-7

"TICKING OFF" STRAIGHT SEGMENTS TO MEASURE LENGTH OF CURVE



SEGMENTS (LINES) OF DIFFERENT LENGTHS
TICK MARKS ON EDGE OF PAPER

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PART IV

DIRECTION

Set 4-1. DIRECTION—POINTS OF THE COMPASS

FRAME 1.

The four principal points of the compass are north, south, east, and west. The four principal directions are, therefore, north, south, east, and ____________.

(180°) (30)

FRAME 31.

To obtain a back azimuth from an azimuth, (add) (subtract) 180° if the azimuth is 180° or less.

(direction) (60)

FRAME 61.

If you don't know the direction of a linear feature, such as a straight road or railroad, you need at least __________________ additional prominent feature to establish the direction and orient the map.

(112° 30′. (Compass readings provide magnetic azimuth; therefore, for the Leavenworth map, grid azimuth = magnetic plus G-M angle. See note adjacent to declination diagram.))

(90)

FRAME 91.

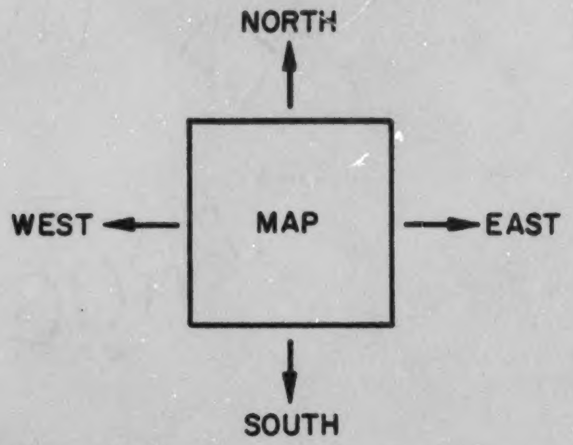
Refer to your LEAVENWORTH map. You are standing in the road junction at coordinates 307578 and observe six radio towers in grid square 3258. What is the magnetic azimuth of a line of sight from your position to the center radio tower at 32855860? (select one response)

a. 61° 0′ b. 70° 30′ c. 80° 0′

(west) (1)

FRAME 2.

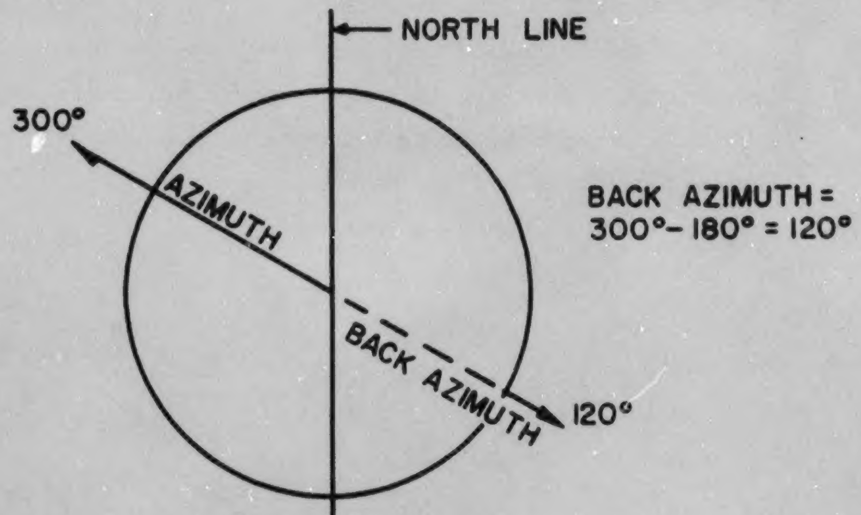
As you know, from your use of other maps (such as an automobile road map) the top of the map is normally north, the right hand margin is to the east, the left hand margin to the west, and the bottom of the map is to the south. The top of the map is normally to the north, to the right is ____________, to the left is ____________, and at the bottom of the map is ____________.


NORTH
WEST
MAP
EAST
SOUTH

(add) (31)

FRAME 32.

Study the figure below. In this case, back azimuth is determined by (adding) (subtracting) 180°. Back azimuth is simply the opposite direction of the azimuth.


NORTH LINE
300°
AZIMUTH
BACK AZIMUTH =
300°- 180° = 120°
BACK AZIMUTH
120°

(one) (61)

FRAME 62.

If you cannot positively identify the necessary features on both ground and map, you may orient your map by determining the direction of ______________ ______________.

(a. 61° 0′ (The grid azimuth is 70° 30′. Therefore the G-M angle is subtracted, or the magnetic azimuth = 70° 30′ − 9° 30′ = 61°) (91)

Set 4-10. INTERSECTION

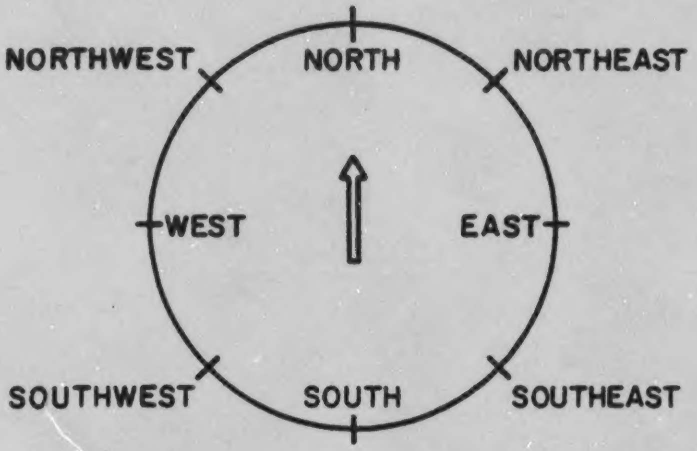
FRAME 92. INFORMATION FRAME.

INTERSECTION is a method by which you can determine the location of an unmapped enemy gun, defensive position, etc., which you can see on the ground, by plotting intersecting azimuths on a map. Accuracy in determining the location depends, in part, on the sharpness of the point of intersection of the azimuths which you draw on your map.

(east, west, south) (2)

FRAME 3.

As you can see from the simplified compass dial below, northeast lies in a direction halfway between north and east. A southwest direction would lie halfway between ______________ and ______________.


NORTHWEST
NORTH
NORTHEAST
WEST
EAST
SOUTHWEST
SOUTH
SOUTHEAST

(subtracting) (32)

FRAME 33.

To obtain a back azimuth from an azimuth, (add) (subtract) 180° if the azimuth is 180° or more.

(true north) (62)

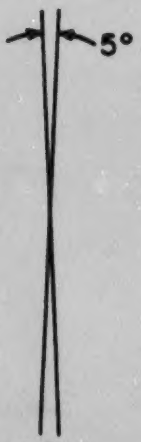
FRAME 63

Once you establish the direction of true north on the ground, you can orient your map because the ____________ of a standard military map is its true north side.

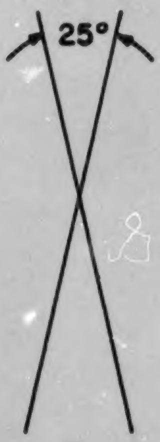
(Go on to the next frame) (92)

FRAME 93.

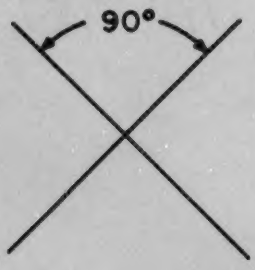
Which set of azimuth lines, plotted below, produce the sharpest point of intersection? ____________________



A



B



C

(west, south) (3)

FRAME 4.

In the lower (southwest) section of your LEAVENWORTH map is the City of Leavenworth. Look at the LEAVENWORTH map and find the City of Leavenworth. You located it by using the direction southwest. Locations can be partly determined by ________________.

(subtract) (33)

FRAME 34.

If the azimuth is less than 180°, you __________ 180° to obtain the back azimuth; if the azimuth is more than 180°, you __________ 180° to obtain the back azimuth.

(top) (63)

FRAME 64.

Complete the following general rules that apply to map orientation by visual inspection.

a. Orient a map by visual inspection only when a ____________ is not available.

b. When orienting a map by visual inspection, select at least ____________ ________________________ prominent terrain features.

c. You must know the direction of a linear feature to avoid ____________ ____________ the orientation.

d. Single features can be used to orient a map by visual inspection only if the observer knows his ____________ on the map.

(C) (93)

FRAME 94.

Refer again to the figure in frame 93. As a general rule, the sharpest intersection is obtained when azimuth sightings are approximately ______________ degrees apart.

(direction) (4)

FRAME 5.

Your unit is located in the City of Leavenworth. It is ordered to proceed south from the city by the 2-lane highway for about 2 miles and rendezvous with another unit at ____________________ Cemetery.

(add, subtract) (34)

FRAME 35.

Determine the back azimuths for the directions listed below and write them in the spaces provided.

a. Grid azimuth = 95°; grid back azimuth = ___________°

b. Magnetic azimuth = 210°; magnetic back azimuth = ___________°

c. Grid azimuth = 359°; grid back azimuth = ___________°

Set 4-8. USE OF PROTRACTOR TO PLOT AZIMUTHS

(compass, two, reversing, location) (64)

FRAME 65. INFORMATION FRAME.

A protractor is an aid to assist you in laying out and measuring azimuths on the map. Panel 4-8 illustrates four types of protractors. Notice that on the circular and square types, all 360 of the degrees of a circle are shown around the center. On the rectangular type, half the degrees, or 180°, are plotted, but values for the full 360° are shown. Some types show both mils and degrees; others are graduated in degrees only. Be sure you understand the protractor you are using, and use the correct values.

(90 degrees (See figure C, frame 93)) (94)

FRAME 95.

Panel 4-13 indicates how intersection is accomplished. To perform intersection, you must take sightings on the unmapped object from at least ____________ known locations.

493

(Mt Calvary) (5)

FRAME 6.

You have located Mt. Calvary Cemetery as about 2 miles south of the City of Leavenworth. Now both units are ordered to proceed to the town of Richardson which is about 1 mile to the ____________________ of Mt. Calvary Cemetery.

a. north b. south c. east d. west

(A. 275°, B. 30°, C. 179°) (35)

FRAME 36. INFORMATION FRAME.

A mil is also used by the map reader to express direction. For military purposes a circle is divided into 6,400 mils. Mils are of particular interest to gunners because a change of 1 mil in the angle of a weapon will change the impact of a shell or bullet a distance of 1 unit for every 1,000 units of range.

(Go on to the next frame) (65)

FRAME 66.

Your protractor has an index point from which the degrees are scaled. If a full 360° are shown, the index point is in the center. It is usually indicated by crossed lines. If your protractor is semicircular or rectangular, only half the degrees are plotted along the semicircle or on three sides of the rectangle. The index point from which the degrees are scaled is in the center of the diameter side of the protractor. It is usually indicated by an arrow. On your protractor, all the degrees are scaled from the ____________________.

(two) (95)

FRAME 96.

If you sight an enemy field fortification which is not shown on your map, you would locate it on the map as follows (pick one response):

a. First take an azimuth from your known position, then move to a new location which can be located on the map and take a second azimuth.

b. First take an azimuth from your known position, then move to another location and take a second azimuth.

(C. east) (6)

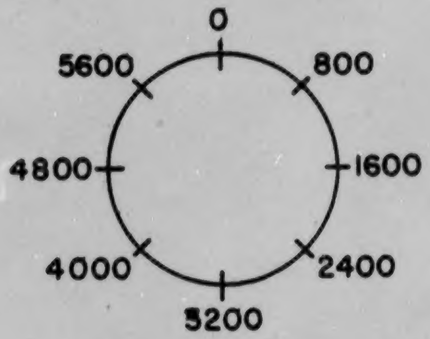
FRAME 7. SUMMARY FRAME.

You have seen that locations can be given by simply stating, for example, that a place is 1 mile along a road to the east or that you should take the 2-lane road south of the city for 2 miles to rendezvous at a cemetery. In the following frames, you will learn how to plot directions on a map and locate a point (for example, an enemy gun position) which may not be on a road or other readily identifiable feature.

(Go on to the next frame) (36)

FRAME 37.

The figure below shows a circle divided into mils. Note that, like an azimuth angle and degrees, mils are also numbered in a (clockwise) (counterclockwise) direction.



(index point) (66)

FRAME 67. INFORMATION FRAME.

To plot an azimuth from a known point, study the steps outlined in Panel 4-9.

(a.) ([illegible]

FRAME 97.

To locate on your map the unmapped object at A in Panel 4-13, you would first orient the map, and then determine ________________ ________________ on the map.

497

Set 4-2. NORTH LINES

FRAME 8.

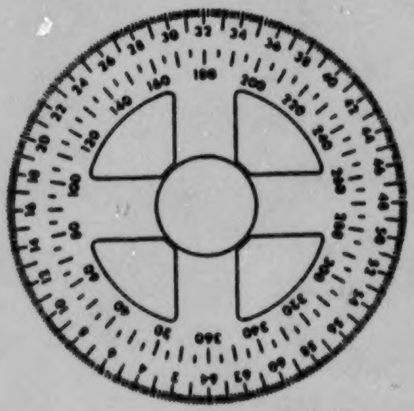
Directions may also be expressed in everyday life as: "on the right side of the road", "on the left bank of the river", etc. In these examples, the ________________ and the ________________ have been used as references from which to express direction.

(clockwise) (37)

FRAME 38.

Compare the mil circle to the degree circle and complete the following table:

Mils		Degrees
1600	=	______
____	=	270°
____	=	225°
5600	=	______



(Go on the next frame) (57)

FRAME 68.

It is seen that the protractor index must be over the ________________
and that the protractor index line (0° to 180°) must be over the ________ ________
line drawn through the point.

(your location) (97)

FRAME 98.

Once your location has been determined, you would take a compass sighting on the unmapped object, convert to a grid azimuth, and then ________________ the ________________ on your map.

(road, river) (8)

FRAME 9.

In military map reading, directions are referenced to a north line instead of to roads, rivers, etc. The ____________________ line serves as a reference line from which directions are expressed.

Set 4-5. DECLINATION DIAGRAM AND G-M ANGLE

(1600 mils = 90°, 4800 mils = 270°, 4000 mils = 225°, 5600 mils = 315°) (38)

FRAME 39. INFORMATION FRAME.

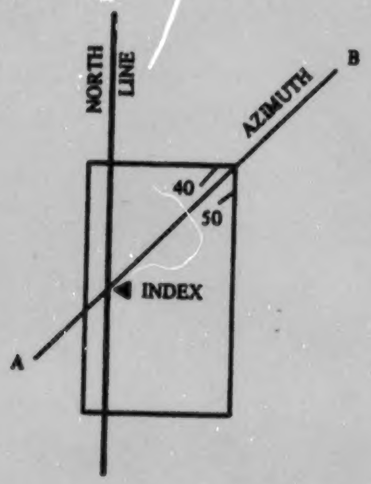
Azimuths and back azimuths can be plotted accurately on a map by referring to the declination diagram in the lower map margin (see LEAVENWORTH map and Panel 4-4). Magnetic declination is the angular difference between true north and magnetic north. However, since the military user is primarily interested in the difference between grid north (on his map) and magnetic north (on his compass), the diagram shows the value of this angle, called the grid-magnetic (G-M) angle, and the relative directions of the different norths. Notes printed next to the diagram tell you how to convert from one type of azimuth to another on that particular map. The angle of grid convergence, which is the difference between true north and grid north, is also shown.

489

(point, north) (68)

FRAME 69.

In the figure below, the protractor has been oriented correctly to measure the azimuth of line A-B, with respect to a grid north line. What is the azimuth of line from point A to point B?



Azimuth of Line A-B = ________°

(plot, azimuth) (98)

FRAME 99.

You then move to a second known point, take another ____________ on the unmapped object, convert to a grid azimuth, then ____________ the second ____________ on your map.

501

(north) (9)

FRAME 10.

Three north lines, from which directions are measured in map reading, are shown in Panel 4-1. Study this panel. Complete the chart below.

SYMBOL		NORTH LINE
↿	a.	________ ________
★	b.	________ ________
"GN" or "Y"	c.	________ ________

(Go on to the next frame) (39)

FRAME 40.

A dashed-line arc is drawn on the declination diagram to connect the ________________ north and magnetic north lines.

491

(45° NOTE: The degrees printed on the edge of the protractor increase in a clockwise direction) (69)

FRAME 70.

To obtain the grid azimuth of a line on a map, you can use as a base line either the grid north line or a line drawn ____________________ to it. You would then use your protractor to measure the angle formed between the base line and the line on the map (Panel 4-9).

(sighting, plot (draw), azimuth) (99)

FRAME 100.

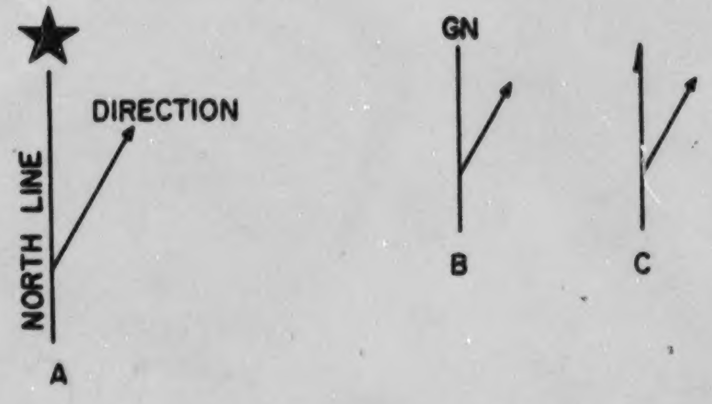
The grid coordinates of the unmapped object can be determined from the point at which the two grid azimuths plotted on the map ________________.

503

(a. Magnetic north, b. True north, c. Grid north) (10)

FRAME 11.

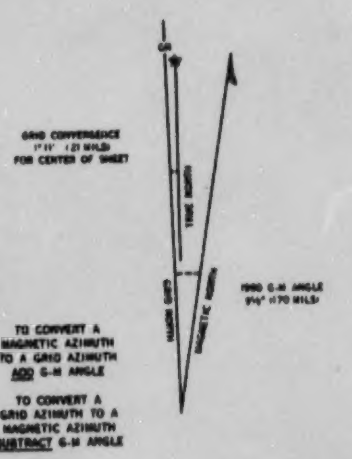
A direction measured from a true north line may be illustrated as shown in A below. Under the diagrams in B and C below, write the name of the north line from which the indicated direction is measured.


NORTH LINE
DIRECTION
A
GN
B
C

(grid) (40)

FRAME 41.

The arc connecting the grid north and magnetic north lines is called a grid-magnetic (G-M) angle. The grid-magnetic angle shown is ________________ degrees or ________________ mils.


GN
GRID CONVERGENCE
1° 11' (21 MILS)
FOR CENTER OF SHEET
TRUE NORTH
GRID NORTH
MAGNETIC NORTH
1960 G-M ANGLE
9½° (170 MILS)
TO CONVERT A MAGNETIC AZIMUTH TO A GRID AZIMUTH ADD G-M ANGLE
TO CONVERT A GRID AZIMUTH TO A MAGNETIC AZIMUTH SUBTRACT G-M ANGLE

(parallel) (70)

FRAME 71.

Refer again to the figure below frame 69. What is the back azimuth of line from point A to point B? (Frame 27 explains how to compute back azimuths)

Back azimuth of line A-B = __________°.

(intersect) (100)

FRAME 101.

Do the following exercise in intersection on your LEAVENWORTH map. Your first known location is at 443662. These coordinates identify your location as being at ______________ ______________. Mark this position A.

(B. grid north, C. magnetic north) (11)

FRAME 12.

Refer again to Panel 4-1 and draw the appropriate symbols of the north lines which are described below.

LINE DERIVED FROM	SYMBOL
a. Compass direction of magnetic north.	a. ________
b. Easting grid lines on a map.	b. ________
c. Earth's north pole.	c. ________

(9½ degrees, 170 mils) (41)

FRAME 42. INFORMATION FRAME.

The date of the G-M angle information is also noted on the diagram. Because the angle may change slightly as the magnetic pole changes its position, this information is usually updated every five years.

495

(225°) (71)

FRAME 72.

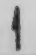
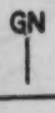
Since the azimuth is less than 180°, the back azimuth is computed by adding 180°. Thus, the back azimuth is 45° + 180° = 225°. If the azimuth is between 180° and 360°, you ____________________ 180° to obtain the back azimuth.

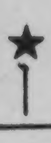
(Flintlock Church) (101)

FRAME 102.

From your position at the church you take a compass sighting of 54°30′ to an enemy gun emplacement. Using the declination diagram on your map, you convert this magnetic azimuth to a grid azimuth of __________°.

507

(a.  ________, b. 

________, c.  ________) (12)

FRAME 13.

In the space provided below, draw the symbols of the three north lines, write the names of the lines, and state how the lines are derived. What determines the direction of each?

	SYMBOL	NAME		HOW DERIVED
a.	________	________	________	________________
b.	________	________	________	________________
c.	________	________	________	________________

(1965) (42)

FRAME 43.

The arc connecting the grid north and magnetic north lines is called a ________ __________ angle.

497

(subtract) NOTE: Back azimuths may also be read directly on your protractor, as explained in Panel 4-9, Note No. 2. (72)

FRAME 73.

For measuring azimuths from 0° to 180°, the protractor is read to the (right) (left) of the north line. For measuring azimuths from 180° to 360°, the protractor is read to the (right) (left) of the north line.

(64°) (102)

FRAME 103.

Use your protractor and a straightedge and plot the grid azimuth of 64° through position A.

509

a.	★	True north	Earth's north pole
b.	/	Magnetic north	Compass direction of magnetic north
c.	GN	Grid north	Easting grid lines on map (13)

FRAME 14.

Any line you draw on the map parallel to the grid north lines shown on your map is a grid north line. Similarly, any lines ________________ to the magnetic north and true north lines shown on your map are magnetic north or true north ________________. Grid north lines and magnetic north lines are most commonly used in determining direction on military maps.

(grid-magnetic (G-M) angle) (43)

FRAME 44.

Refer to the LEAVENWORTH map provided with this text. Locate the declination diagram in the bottom margin. The G-M angle on the LEAVENWORTH map is __________ degrees or __________ mils and was prepared in ____________.

(right, left) (73)

FRAME 74.

Turn to Panel 4-10. Draw a line connecting points A and B, points A and C, and points A and D. Use your protractor to find the azimuths of these lines and enter your answers in the spaces provided below.

Line	**Azimuth**
Point A to Point B	________°
Point A to Point C	________°
Point A to Point D	________°

(Go on to the next frame) (103)

FRAME 104.

You would now move to a second known position, for example, to the road junction at 450695. Label this position B.

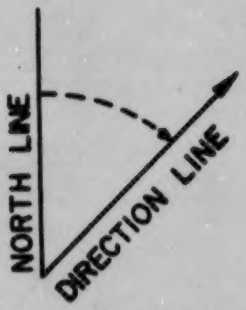
511

Set 4-3. AZIMUTH MEASUREMENT

(parallel, lines) (14)

FRAME 15.

The most common military method of expressing a direction is by using an azimuth. The figure below shows a north line and a direction. The angle between the north line and the direction line, shown by a dashed line, is an __________.



(9½ degrees, 170 mils, 1960) (44)

FRAME 45.

The angle at which a magnetic north line plotted on a map intersects an easting grid line is known as the __________ __________.

Line	Azimuth
Point A to Point B	45°
Point A to Point C	92°
Point A to Point D	226° (74)

FRAME 75.

Turn to Panel 4-11. Using easting grid line 41 as a base line, measure the azimuth of the line drawn from Point A to Point B. The azimuth is __________ degrees.

(Go on to the next frame) (104)

FRAME 105.

From your new location at the road junction (position B), you take a compass sighting of 119° to the gun emplacement. You convert this to a grid azimuth of ________° ________'.

(azimuth) (15)

FRAME 16.

The arrow on the dashed line in frame 15 shows that the azimuth angle is measured in a (clockwise) (counterclockwise) direction from the north line.

(G-M angle) (45)

FRAME 46.

Study the declination diagram on the map. The GRID NORTH line is parallel to the ________________ grid lines on the map.

503

(63 degrees) (75)

FRAME 76.

Refer to Panel 4-11. The line from Point A to Point B has a __________ azimuth of 63 degrees.

(128° 30′) (105)

FRAME 106.

Plot the grid azimuth of 128° 30′ through position B.

515

(clockwise) (16)

FRAME 17.

All azimuths are measured in the same manner—they are measured in a ________________ direction from the north line.

(easting) (46)

FRAME 47.

If a magnetic north line were plotted on the LEAVENWORTH map, it would intersect an easting grid line at an angle of __________ degrees __________ minutes.

(grid) (76)

FRAME 77.

Again turn to Panel 4-11. Using easting grid line 42 as a north line, measure the azimuth of the line drawn from Point X to Point B. The azimuth is ________ degrees.

(Go on to the next frame) (106)

FRAME 107.

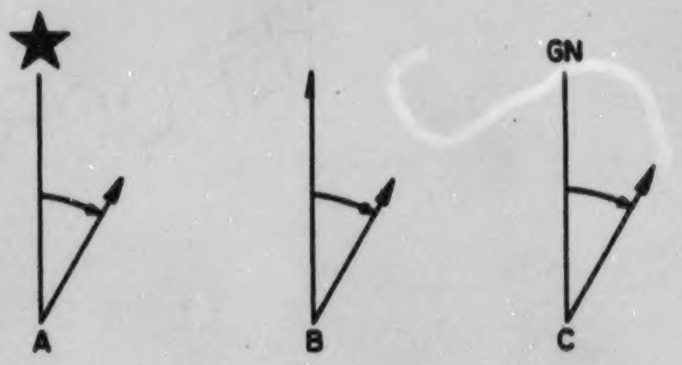
Extend the two azimuths until the lines intersect. The grid coordinates of the enemy gun emplacement are ________________.

517

(clockwise) (17)

FRAME 18.

Figure A shows a "true azimuth angle", so named because the azimuth angle shows a direction as related to a true north line. B shows a ________ ________ ________ and C shows a ________ ________ ________.



Set 4-6. USE OF COMPASS TO ORIENT MAP

(9°, 30′) (47)

FRAME 48. INFORMATION FRAME.

The magnetic compass is the most commonly used and simplest instrument for measuring directions and angles in the field. A lensatic compass is shown in Panel 4-2.

507

(63 degrees) (77)

FRAME 78.

Refer to Panel 4-11. The line from Point X to Point B has a ____________ azimuth of 63 degrees.

(473676) (107)

Set 4-11. RESECTION

FRAME 108. INFORMATION FRAME.

Panel 4-14 indicates how resection is accomplished. To perform resection you must take sights on ________________ or more objects of known location from your unknown location.

519

(B. magnetic azimuth angle; C. grid azimuth angle) (18)

FRAME 19.

Azimuth angles are commonly expressed in degree units of angular measure. A true azimuth of 45 degrees (written as 45°) is, therefore, a direction. It tells us that—

a. The north line used as a reference for measuring was a ____________ ____________ line.

b. The azimuth of 45° was measured in a ____________ direction.

(Go on to the next frame) (48)

FRAME 49.

Look at the compass dial in Panel 4-3. You see that it is graduated (has measurement ticks) in ________ and ________. The outer ring of numbers contains the ________ graduations and the inner ring, the ________ graduations.

(grid) (78)

FRAME 79.

All lines drawn through a point and parallel to easting grid lines can be used to measure ________________ ________________.

(two) (108)

FRAME 109.

Study Panel 4-14. The first thing you should do when performing resection is to ____________ the ____________.

(a. true north, b. clockwise) (19)

FRAME 20.

A degree is $\frac{1}{360}$ part of a circle. Therefore, a circle contains _______ degrees.

(mils, degrees, mil, degree) (49)

FRAME 50.

A closer look at a portion of the dial (Panel 4-3) indicates that the measurement marks on the mil scale are separated by __________________ mils, and those on the degree scale are separated by _________________ degrees.

(grid azimuth) (79)

FRAME 80.

Also, because a straight line crosses all grid norths at the same angle, the straight line can be extended in either direction and a grid azimuth taken at the new points it crosses the ______________ ______________ ______________.

(orient, map) (109)

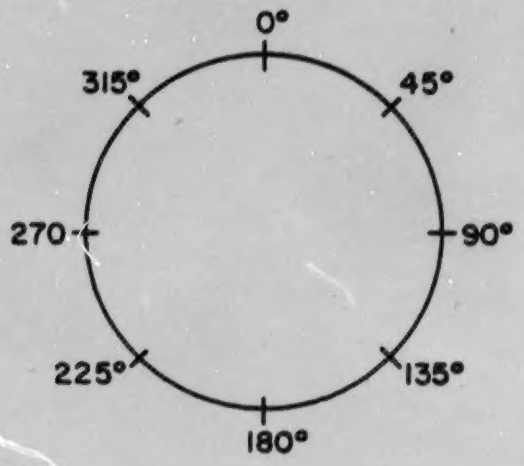
FRAME 110.

Do the following exercises in resection on your LEAVENWORTH map. From your present unknown location, you take a compass sighting on the road junction at 393518. Mark the road junction on the map, point A. The magnetic azimuth to point A is 281° 30′. This means the grid azimuth will be __________°.

(360) (20)

FRAME 21.

The figure below shows a circle divided into degrees. Note that like an azimuth, degrees are numbered in a (clockwise) (counterclockwise) direction.



(20 mils, 5 degrees) (50)

FRAME 51. INFORMATION FRAME.

To use the compass, the sighting slot in the eyepiece, the sighting wire in the front cover, and the target are alined. The magnetic azimuth can be read by glancing down at the dial through the lens, and reading the value under the index line on the face of the compass.

513

(grid north lines) (80)

FRAME 81.

Line A-B in Panel 4-11 crosses each easting grid line at the same ________. Therefore, the grid azimuth is the same when measured at ____________ easting grid line.

(291°) (110)

FRAME 111.

What is the back grid azimuth of 291°? ____________

525

(clockwise) (21)

FRAME 22.

Each degree is further divided into 60 minutes (written as 60′). Therefore, 9½ degrees can be written ________° ________′.

(Go on to the next frame) (51)

FRAME 52.

Azimuths are read by observing the mil or degree graduation appearing under the index line. Indicate in the spaces provided below the magnetic azimuths which are shown on the compass dials pictured in Panel 4-5.

a. ________ degrees, ________ mils

b. ________ degrees, ________ mils

(angle, any) (81)

FRAME 82.

Determine the grid azimuth of the line in Panel 4-11 which is drawn from Point Y to Point B. The grid azimuth is ____________________.

(111°) (111)

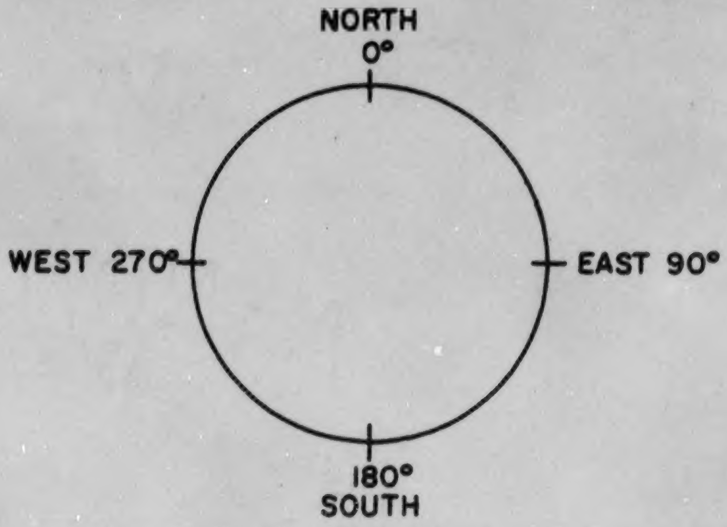
FRAME 112.

Plot the back grid azimuth of 111° from point A and extend the line toward the general direction of your location. The next step in resection is to take a ____________________ ____________________ on a second identified terrain feature.

(9° 30′) (22)

FRAME 23.

Consider that you are standing in the center of the circle shown below. When you face towards any north (true, grid or magnetic) you are facing 0° (or 360°). When facing to the west, you are facing ________ degrees.



(a. 52 degrees or 940 mils, b. 266 degrees or 4740 mils) (52)

FRAME 53. INFORMATION FRAME.

When you place a map so that all its directions are alined with corresponding directions on the ground, the map is said to be oriented.

(80°) (82)

FRAME 83.

Turn to Panel 4-12. Determine the grid azimuths of the lines indicated below, and complete the chart. (Hint: Extend lines A-X, etc. in order to read on protractor.)

Line	Grid Azimuth
From Point A to Point X	____________°
From Point B to Point X	____________°
From Point C to Point X	____________°

(compass sighting) (112)

FRAME 113.

You now sight on the second identified terrain feature, a road junction at 426522. Mark this road junction as point B. You then determine the magnetic azimuth to point B to be 33°. What is the grid azimuth? ____________________

(270 degrees) (23)

FRAME 24.

When standing at the center of the circle facing towards the north, and desiring to face towards the east, you must turn __________ degrees in a clockwise direction.

(Go on to next frame) (53)

FRAME 54.

To orient a map, you position the map so that map directions are alined with corresponding ____________________ directions.

Set 4-9. CONVERSION OF AZIMUTHS

(45°, 90°, 329°) (83)

FRAME 84.

Refer to your LEAVENWORTH map. Use your protractor to measure the grid azimuth from BM 761 at coordinates 419491, to BM 972 at coordinates 489516. The grid azimuth is _________° _________′.

(42° 30′) (113)

FRAME 114.

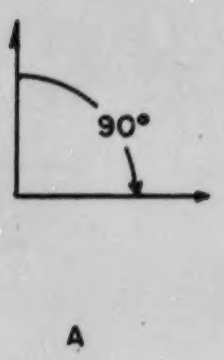
What is the back grid azimuth of 42° 30′? ________________

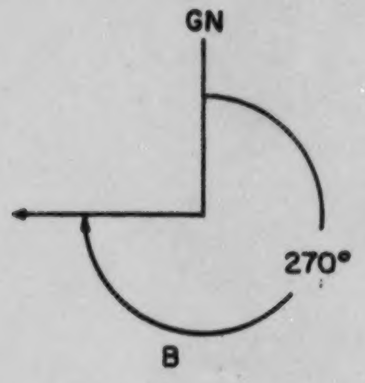
531

(90 degrees (90°)) (24)

FRAME 25.

In the spaces below, write the azimuths indicated in sketches A and B.





A. __________ azimuth of __________° B. __________ azimuth of __________°

(ground) (54)

FRAME 55.

A map can be oriented with a compass. Panel 4-6 shows how this orientation is accomplished. Study this panel. The compass sighting wire is placed over an ________________________________ line.

(70° 45′ (45′ is estimated, as angle is greater than 70° 30′ and less than 71°)) (84)

FRAME 85.

After determining the grid azimuth from BM 761 to BM 972 to be 70° 45′, you can determine the magnetic (compass) azimuth by **(adding) (subtracting)** 9° 30′.

(222° 30′) (114)

FRAME 115.

Plot the back grid azimuth of 222° 30′. Extend the plotted line to intersect with the back azimuth line you have drawn from point A. You are located at the intersection of these two lines which is at (coordinates) ____________________.

(A. Magnetic azimuth of 90°, B. Grid azimuth of 270°) (25)

FRAME 26.

Above the captions below, sketch in the azimuths called for. Show the angle size and direction of measurement.

A. Grid azimuth of 210°. **B. Magnetic azimuth of 90°.**

(easting grid) (55)

FRAME 56.

Following orientation, all map lines are ________________ to their corresponding lines on the ground.

(subtracting. (Note: The conversion rules for converting grid and magnetic azimuths are printed adjacent to the declination diagram in the bottom margin of each map. See your LEAVENWORTH map.)) (85)

FRAME 86.

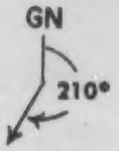
The magnetic azimuth from BM 761 to BM 972 is ________° ________′.

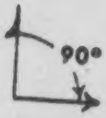
(415510) (115)

FRAME 116. INFORMATION FRAME.

In rare instances, where you are standing on a linear terrain feature, which can be identified on your map (e.g., a railroad, road, river bank, etc.) it may be necessary to sight on only one identified terrain feature to perform resection. Use your LEAVENWORTH map to perform the following resection problem to illustrate how only one azimuth need be drawn to locate your position when you are standing on an identified linear terrain feature.

Set 4-4. BACK AZIMUTH MEASUREMENT





(A. Grid azimuth of 210°, B. Magnetic azimuth of 90°) (26)

FRAME 27. INFORMATION FRAME.

In map reading, it is often required that a back azimuth be determined. A back azimuth is the reverse direction of an azimuth. It is comparable to doing an "about-face". It is the opposite direction of the azimuth. Back azimuths are used to determine the position of the observer or unit when the location is not known. This will be discussed in later frames.

Set 4-7. ORIENTATION OF MAP BY VISUAL INSPECTION

(parallel) (56)

FRAME 57.

When a compass is not available, a map can be oriented as shown in Panel 4-7 by ____________________ inspection. Orientation of a map by visual inspection is recommended only when a ____________________ is not available.

525

(61° 15′) (86)

FRAME 87.

Refer to your LEAVENWORTH map. You are located at Fancy Bottom School, at coordinates 339647. The grid azimuth from your position to Coffin School, at coordinates 306600, is ________°.

(Go on to the next frame) (116)

FRAME 117.

You are standing on the Burlington and Quincy railroad, somewhere between IATAN in grid square 2971 and WESTON in grid square 3664. You make a compass sighting on the church steeple in the town of KICKAPOO, at 30306295, and read a magnetic azimuth of 215° 30′, which is a grid azimuth of __________.

537

(Go on to the next frame) (27)

FRAME 28.

If you desired to turn from facing north (0°) to facing south, you would turn ________ degrees.

(visual, compass) (57)

FRAME 58.

Orientation of a map by visual inspection consists of adjusting the position of the map until distinctive features identified on the ground are in the same relative positions on the map. At least ____________ prominent features are usually needed.

527

(215°) (87)

FRAME 88.

The magnetic (compass) azimuth of the line from Fancy Bottom School to Coffin School is _________° _________.

(225°) (117)

FRAME 118.

Plot the back azimuth of 225°, which is _________°, from the church to the railroad.

539

(180°) (28)

FRAME 29.

If you are facing east (90°) and do an about-face, you will be facing ______ which is ______ degrees.

(two) (58)

FRAME 59.

If you know your ground position and can identify it on the map, you can orient the map by alining your plotted position with at least one other feature identified on the map and visible on the ground. To use this method, you must be able to locate your position and another feature both on the ______ and on the ______.

(205° 30′. (See conversion rule adjacent to declination diagram on LEAVENWORTH map.)) (88)

FRAME 89.

The magnetic azimuth of a line from Coffin School to Fancy Bottom School is ________°

(45°) (118)

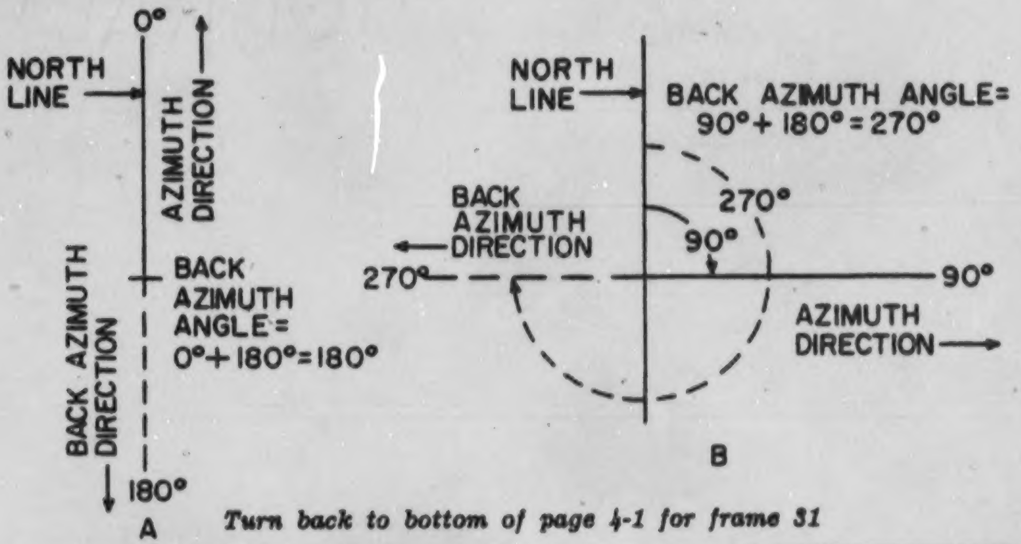
FRAME 119.

Your location on the railroad is determined by the intersection of the back grid azimuth line of 45° with the railroad. You are located on the railroad at coordinates ________________.

(West, 270°) (29)

FRAME 30.

The facing movements, just discussed, are shown as azimuths and back azimuths below. Both back azimuths were obtained by adding ____________° to the original direction (azimuth) in which you were facing.


0°
NORTH LINE
AZIMUTH DIRECTION
BACK AZIMUTH DIRECTION
BACK AZIMUTH ANGLE = 0°+180°=180°
180°
A
NORTH LINE
BACK AZIMUTH ANGLE= 90°+180°=270°
270°
90°
BACK AZIMUTH DIRECTION
270°
90°
AZIMUTH DIRECTION
B

Turn back to bottom of page 4-1 for frame 31

(ground, map) (59)

FRAME 60.

A linear feature, such as a road, railroad, or stream bed, is useful for orientation if you can determine its ____________.

Turn back to top of page 4-2 for frame 61

531

(25° 30′. (This is a back magnetic azimuth of the magnetic azimuth you calculated in the previous frame; therefore it may be obtained as 205° 30′ − 180° = 25° 30′.)) (89)

FRAME 90.

Refer to your LEAVENWORTH MAP. You are located at COFFIN SCHOOL at coordinates 306600, and take a compass sighting to the water tower located at coordinates 333589. If your compass reading is 103°, the grid azimuth to the water tower is ________° ________′.

Turn back to bottom of page 4-2 for frame 91

(336663) (119)

FRAME 120.

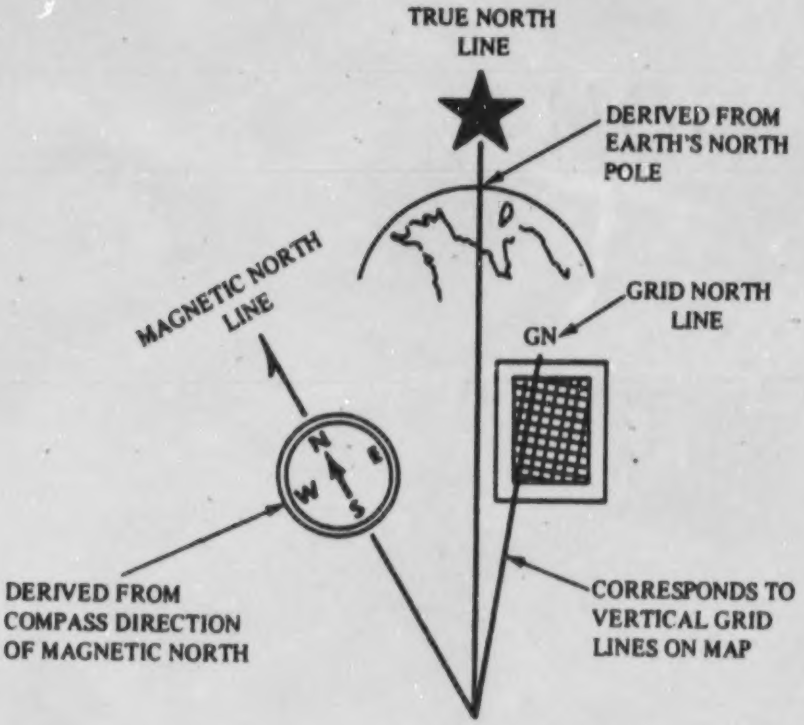
Unless you are standing on a ________________ terrain feature which you can identify on the map, at least ________________ features appearing on the map must be sighted from your unknown location in order to accurately accomplish resection.

513

532

PANEL 4-1

MAGNETIC NORTH, TRUE NORTH, AND GRID NORTH

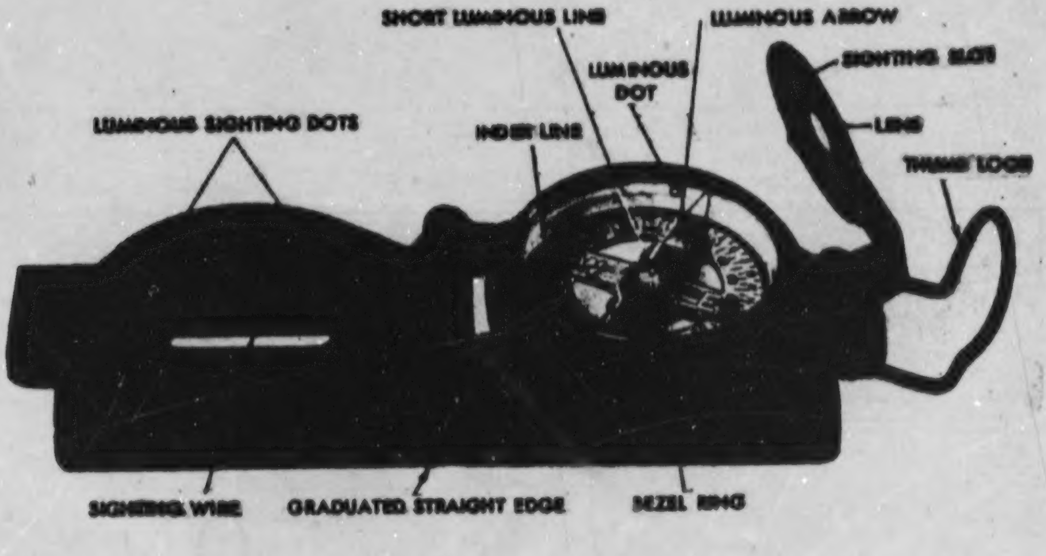

TRUE NORTH LINE
DERIVED FROM EARTH'S NORTH POLE
MAGNETIC NORTH LINE
GRID NORTH LINE
GN
N
E
W
S
DERIVED FROM COMPASS DIRECTION OF MAGNETIC NORTH
CORRESPONDS TO VERTICAL GRID LINES ON MAP

NOTE: THE LETTER "Y" CAN BE USED INSTEAD OF "GN"

544

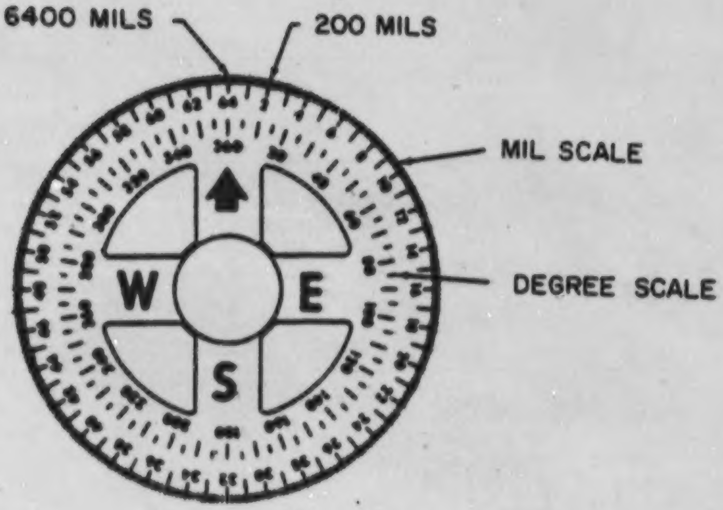
PANEL 4-2

LENSATIC COMPASS

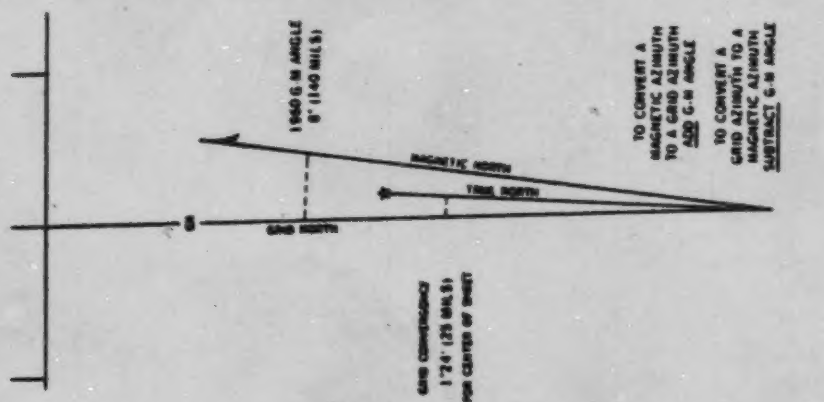

SHORT LUMINOUS LINE
LUMINOUS ARROW
SIGHTING SLOT
LUMINOUS DOT
LENS
LUMINOUS SIGHTING DOTS
INDEX LINE
THUMB LOOP
SIGHTING WIRE
GRADUATED STRAIGHT EDGE
BEZEL RING

PANEL 4-3

COMPASS DIAL

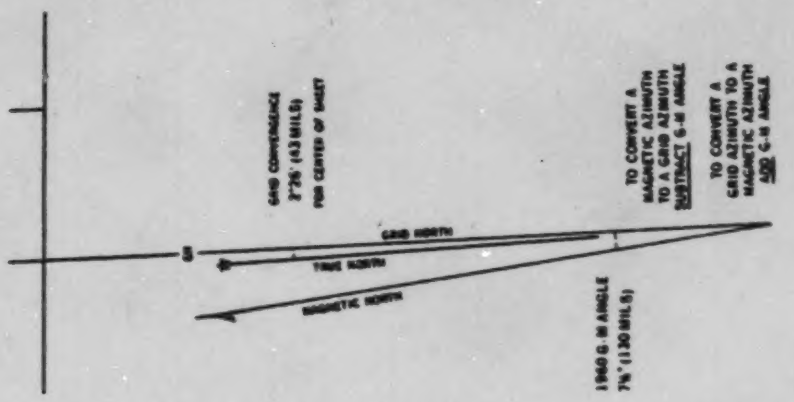

6400 MILS
200 MILS
MIL SCALE
DEGREE SCALE
W
E
S

PANEL 4-4
DECLINATION DIAGRAMS


GRID NORTH
TRUE NORTH
MAGNETIC NORTH
1960 G-M ANGLE
8° (140 MILS)
GRID CONVERGENCE
1°24' (25 MILS)
FOR CENTER OF SHEET

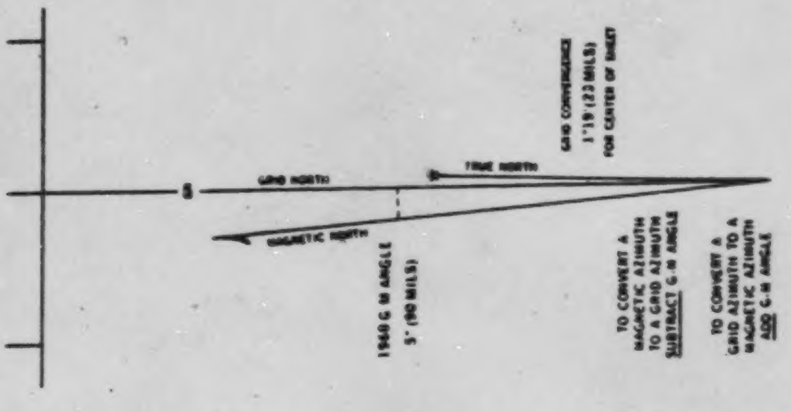
TO CONVERT A MAGNETIC AZIMUTH TO A GRID AZIMUTH ADD G-M ANGLE

TO CONVERT A GRID AZIMUTH TO A MAGNETIC AZIMUTH SUBTRACT G-M ANGLE


GRID CONVERGENCE
2°26' (43 MILS)
FOR CENTER OF SHEET
GRID NORTH
TRUE NORTH
MAGNETIC NORTH
1960 G-M ANGLE
7½° (130 MILS)

TO CONVERT A MAGNETIC AZIMUTH TO A GRID AZIMUTH SUBTRACT G-M ANGLE

TO CONVERT A GRID AZIMUTH TO A MAGNETIC AZIMUTH ADD G-M ANGLE

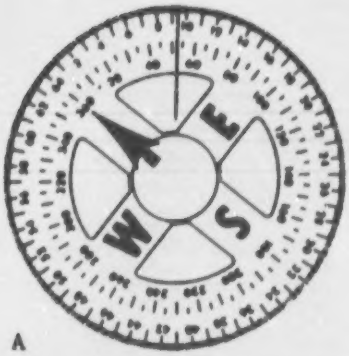

GRID CONVERGENCE
1°19' (23 MILS)
FOR CENTER OF SHEET
GRID NORTH
TRUE NORTH
MAGNETIC NORTH
1960 G M ANGLE
5° (90 MILS)

TO CONVERT A MAGNETIC AZIMUTH TO A GRID AZIMUTH SUBTRACT G-M ANGLE

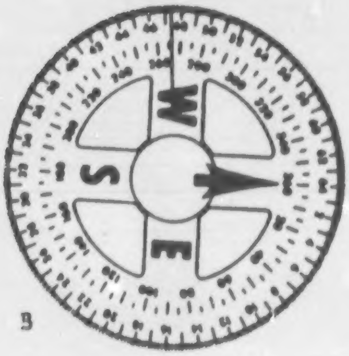
TO CONVERT A GRID AZIMUTH TO A MAGNETIC AZIMUTH ADD G-M ANGLE

PANEL 4-5

MAGNETIC AZIMUTHS READ FROM COMPASS



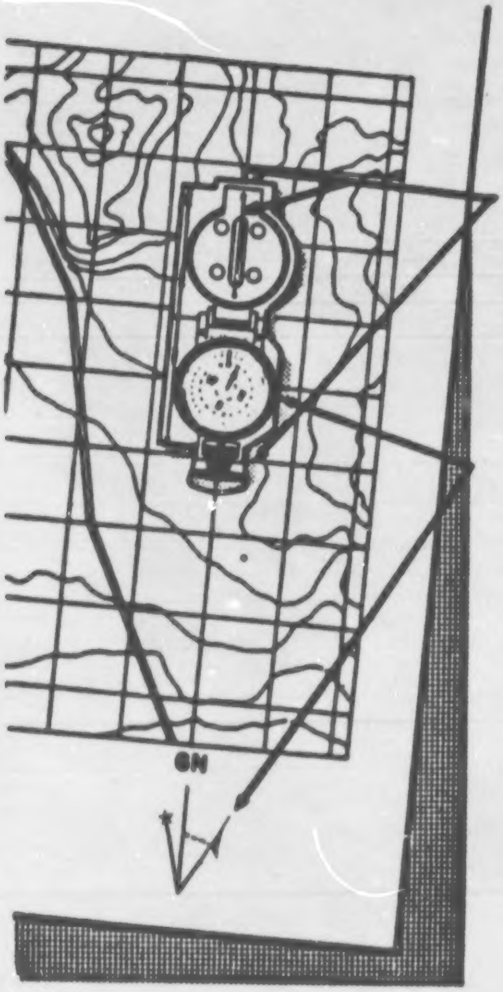
A



B

PANEL 4-6

TO ORIENT YOUR MAP BY COMPASS

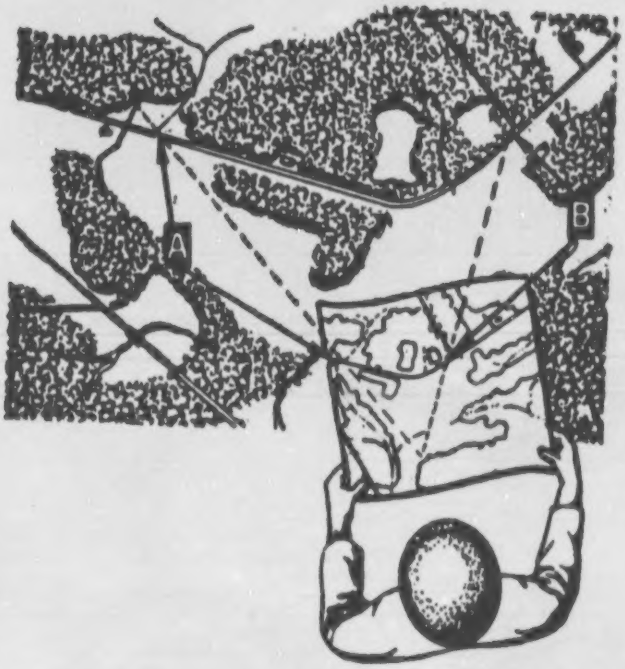


1 Aline sighting wire and notches at front and rear of compass over any north-south grid line. This places the index line on the face of the compass parallel to grid north.

2 Rotate map and compass together until the angle formed by the north needle and index line is the same value and relationship as shown for the G-M angle in the declination diagram in the map margin.

PANEL 4-7

ORIENTING A MAP BY VISUAL INSPECTION



1. At least two prominent features such as A and B are usually needed for orientation. You must locate them on the map as well as on the ground, and adjust the map until both ground features are alined with their map symbols.

2. If you can locate your position on the map, you can orient it by alining your plotted position with one additional prominent feature which is visible from your position and plotted on the map.

3. If the feature is linear, it is necessary to know its direction to avoid reversing the orientation. If you cannot determine the direction of the linear feature, at least one additional prominent feature is needed to orient the map.

4. A map may be roughly oriented by determining the direction of true north. The top of a standard military map represents true north. You can determine the approximate direction of true north on the ground by various expedient methods, such as the following:

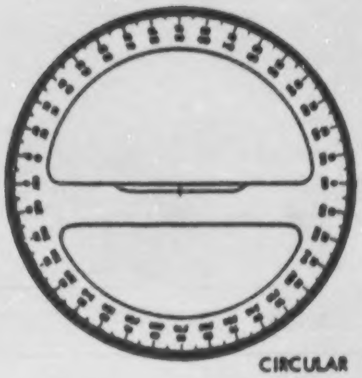
a. Observe the movement of the sun. In the northern hemisphere, it moves from east to south (at noon) to west.

b. Locate Polaris, the North Star.

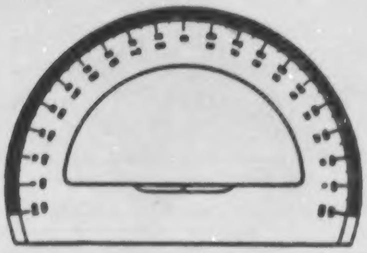
c. Observe the movement of shadows. They move from west to north (at noon) to east.

If you stand with east on your right, you will be facing north

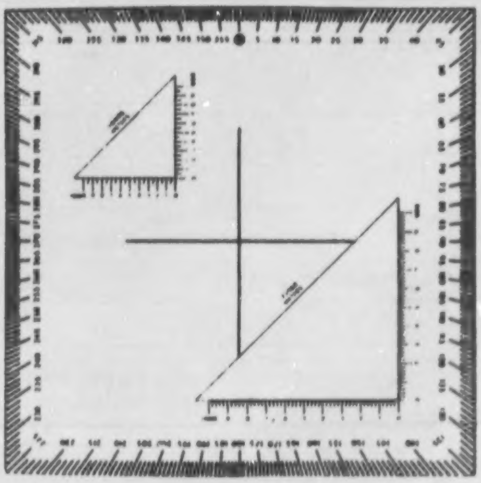
PANEL 4-8



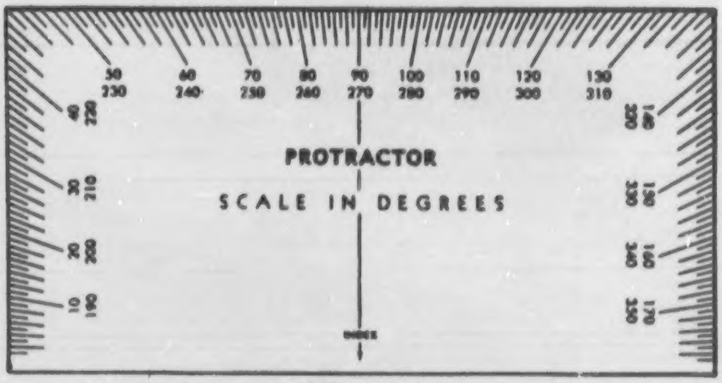
CIRCULAR



SEMICIRCULAR



SQUARE


50
230
60
240
70
250
80
260
90
270
100
280
110
290
120
300
130
310
40
220
140
320
30
210
150
330
20
200
160
340
10
190
170
350
PROTRACTOR
SCALE IN DEGREES
INDEX

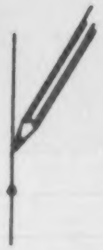
RECTANGULAR

Protractors

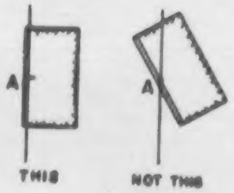
PANEL 4-9

USE OF PROTRACTOR IN PLOTTING AZIMUTHS

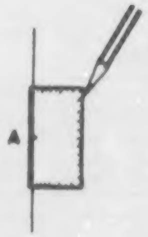
Step 1: Select a point from which the azimuth will be drawn, and construct a north line through the point parallel to an easting (north-south) grid line. There are several ways to construct the north line. One of the simplest is to use the map scale on your protractor as though reading the grid coordinates of the point (see Part II, frame 32). The leg of the map scale which runs through the point is parallel to the easting grid lines. Mark the place where this leg intersects the lower northing (east-west) grid line (the corner of the scale), and draw a line through both that point and the original point, extending it as necessary.



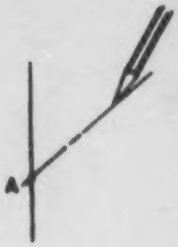
Step 2: Place the protractor index over the point, making certain the protractor index line (the 0° to 180° line) is over the north line which was drawn in step 1.



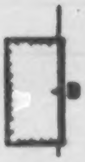
Step 3: Place a mark on the paper along the protractor edge at the desired azimuth. In the example, a 50° grid azimuth is given. Azimuths are normally plotted from grid lines on a map, and therefore must be grid azimuths. If you are given a magnetic (compass) azimuth you must consult the conversion rules in the bottom margin of your map. For the Leavenworth map, you see that you must add 9½° to convert from magnetic to grid azimuth. Hence, if a 50° magnetic azimuth were given, you would plot a 59½° grid azimuth on the map.



PANEL 4-9 (Continued)



Step 4: Remove the protractor and draw a line connecting point A with the mark drawn at 50°. The line is at a grid azimuth of 50° from the point on the north line which was drawn in Step 1.



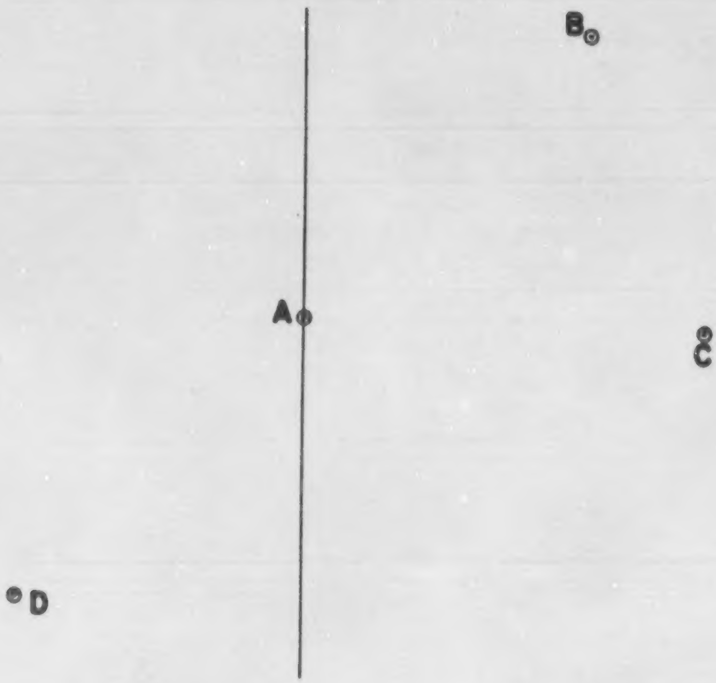
Note #1: If you are using a semicircular or rectangular protractor, the protractor is reversed, as shown at the right, for plotting azimuths greater than 180°. When you use the protractor in this position, you read the inner row of angle values (180° to 360°). The requirement to convert from magnetic azimuth to grid azimuth before plotting on the map applies regardless of the position of the protractor.

Note #2: Back azimuths may also be read directly from your protractor. If your protractor is circular or square, extend the azimuth line to intersect the opposite side of the protractor and read the back azimuth, making sure that the azimuth line passes through both the point and the protractor index point. If you have a rectangular protractor, with the double row of degree values, notice that the the inner row of values corresponds to the back azimuths for the outer row of values, and vice versa. For example, if you measure an azimuth of 40°, note that the corresponding back azimuth, 220°, is given on the inner scale for the same measurement.

542

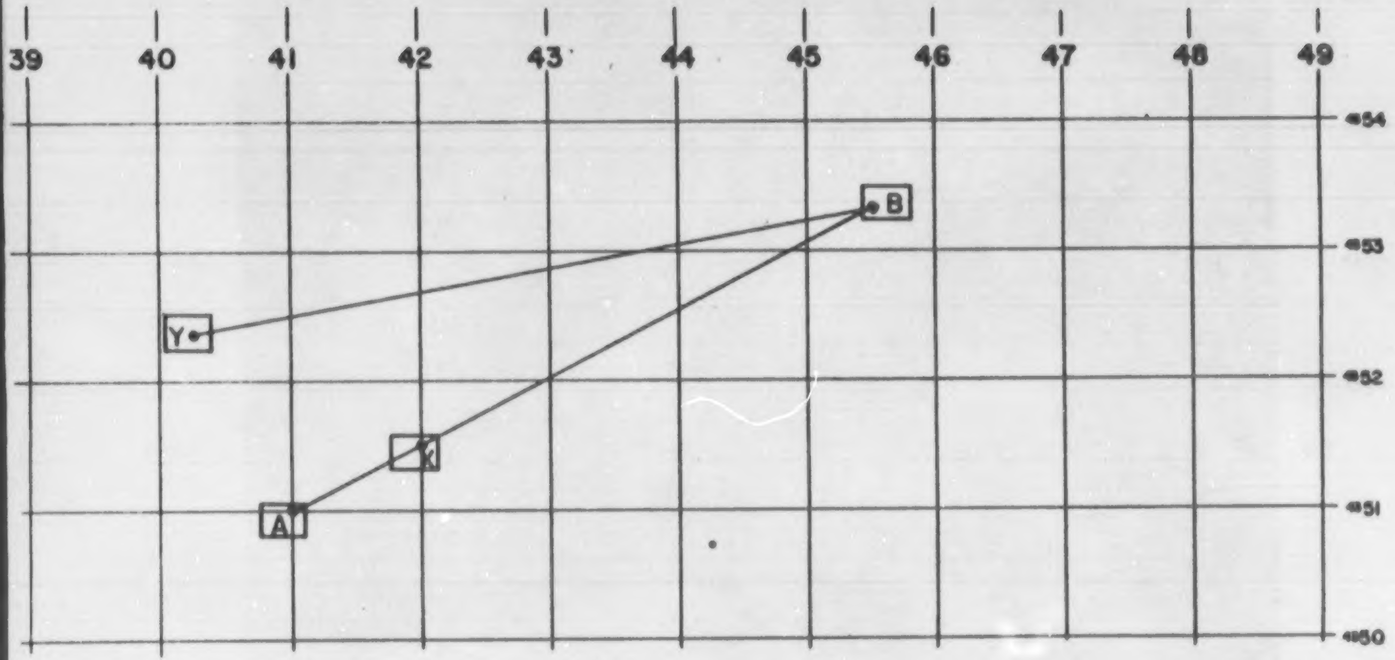
PANEL 4-10

MEASURING AZIMUTHS



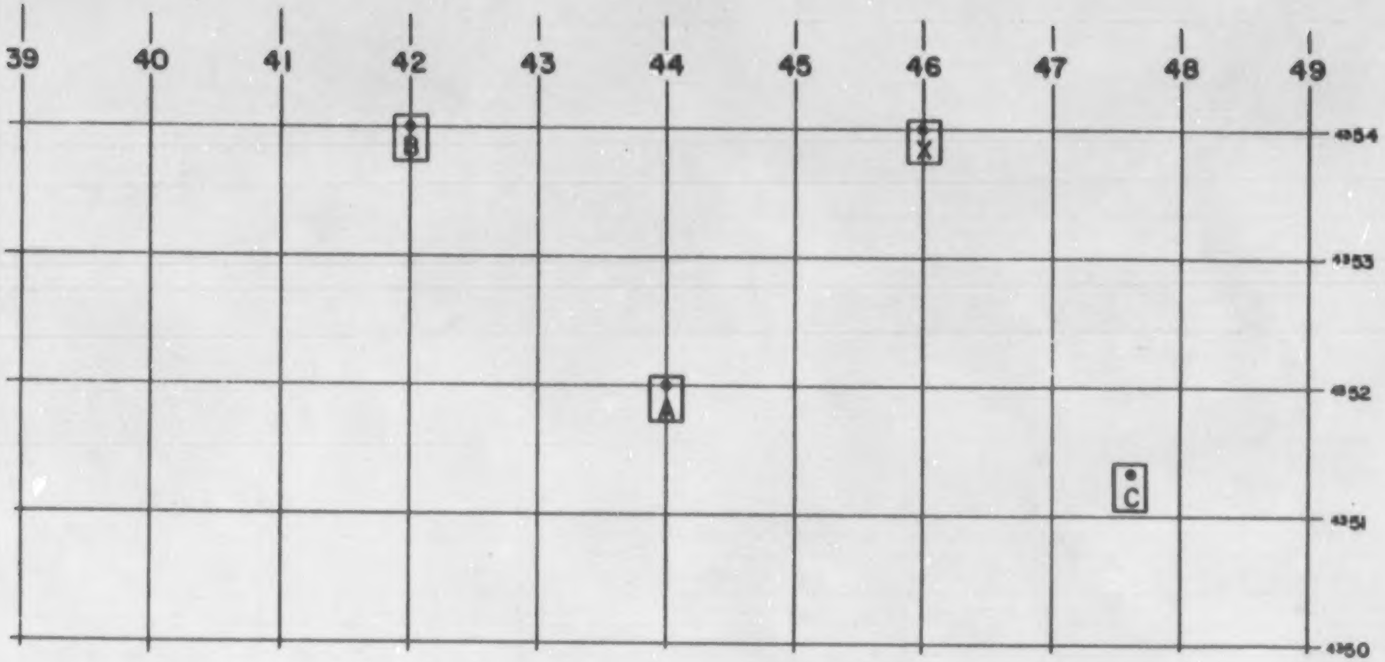
555

GRID AZIMUTHS AND GRID LINES


39
40
41
42
43
44
45
46
47
48
49
54
53
52
51
50
B
Y
X
A

PANEL 4-11

DETERMINING GRID AZIMUTHS

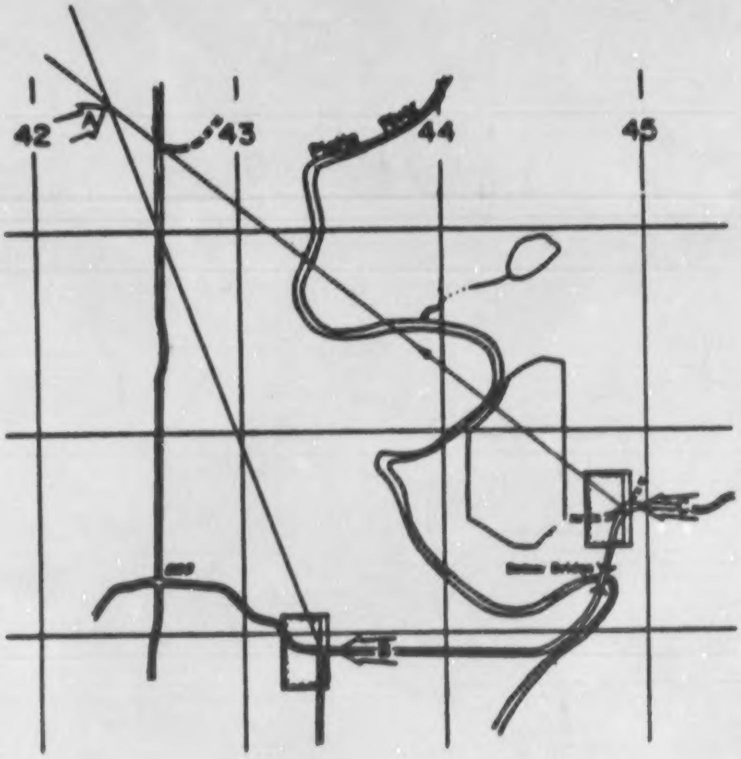

39
40
41
42
43
44
45
46
47
48
49
4354
4353
4352
4351
4350
B
X
A
C

PANEL 4-12

PANEL 4-13

PERFORMING INTERSECTION

Locating an unknown point by successively occupying two (or more) known positions and sightings on the unknown point is called INTERSECTION.



Method:

A. Orient map.

B. Determine your location (at B), take sighting to unknown point (A), convert to grid azimuth, and plot azimuth (B-A) on your map.

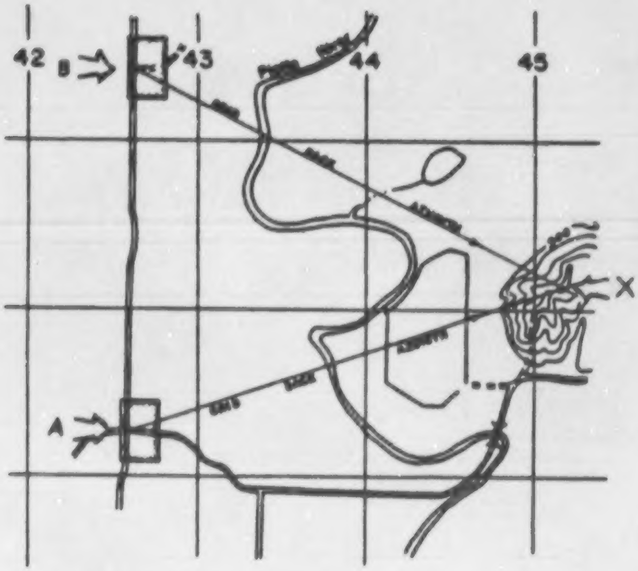
C. Move to new point (C), determine location, sight on A, convert to grid azimuth, plot azimuth (C-A) on your map.

D. Intersection of azimuths (B-A and C-A) on your map pinpoints map location of previously unknown point A.

PANEL 4-14

PERFORMING RESECTION

Locating your position by sighting on two known features is called RESECTION.



METHOD:

A. Orient map.

B. Identify two (or more) prominent terrain features(A and B) and locate these on your map.

C. Take compass sightings on features A and B; convert to grid azimuths.

D. Plot back grid azimuths from A and B toward your position on the map.

E. Intersection of the back azimuths on your map pinpoints your previously unknown position (X).

PART V

RELIEF

Set 5-1. CONTOUR LINES AND ELEVATION

FRAME 1.

The differences in shape and height of the earth's surface are called relief. On a map, relief is shown by symbols called contour lines. Contour lines show the __________________ (differences in heights) of the ground.

(less, supplementary) (19)

FRAME 20.

Supplementary contours are shown by dashed lines on the map. Refer to the marginal information (bottom center) on the LEAVENWORTH map. What is the interval at which supplementary contours are drawn?

a. 5-foot b. 10-foot c. 20-foot

(960 feet) (38)

FRAME 39.

Often, the point whose elevation you wish to determine falls between the contour lines shown on the map. If it falls in the middle or close to the middle of the space between contours, you give it the value that is halfway between the contours. If it is closer to the lower or upper contour, you give it the value of the closest contour. If another road junction were halfway between the 960- and 980-foot contour lines (horizontal distance) it would be considered halfway between the 960- and 980-foot elevations (vertical distance) or at an elevation of ______________.

(profile) (57)

FRAME 58.

Step 2. Find the value of the highest and lowest contour lines that cross or touch the profile line. In Panel 5-13 what is the higest contour elevation, and what is the lowest?

Highest	Lowest
a. 540	a. 400
b. 600	b. 420
c. 640	c. 460

(relief) (1)

FRAME 2.

On the map, relief (changes in height and shape of the ground) is pictured by the brown lines called contours or contour lines. Since a hill is a relief feature, it is shown on the map by ________________.

(b. 10-foot. Note: Supplementary contours are usually added at one-half the contour interval.) (20)

FRAME 21.

Each contour line, whether index, intermediate or supplementary, represents the same elevation wherever it appears on the map. In other words, all points on a contour line are at the same ________________.

(970 feet) (39)

FRAME 40.

Spot elevations and bench marks (identified in the legend of your LEAVENWORTH map) are elevations which have been measured by surveyors or map makers at prominent locations, such as road junctions and hilltops. Along the south edge of the LEAVENWORTH map, the number 946, between grid lines 31 and 32, refers to a road junction. This is the ________________ of the junction.

(b. 600, c. 460) (58)

FRAME 59.

Step 3. Add one contour interval value to the highest and subtract one value from the lowest contour elevation. This will take care of the hilltops and draws. The contours to be drawn in the profile, including the added and subtracted values, range from ______ to ______.

a. 400, 600 b. 420, 640 c. 440, 620

(contours) (2)

FRAME 3.

Refer to coordinates 4152 on your LEAVENWORTH map. Note the many brown ________________ ________________ which indicate hilly terrain.

(elevation) (21)

FRAME 22.

The contour interval is the vertical distance represented between one contour and the next one to it. Whatever the horizontal distance between the two contours, the vertical distance between them is the ________________.

(elevation) (40)

FRAME 41.

Prominent features (hilltops, road junctions) may be referred to by their elevations. For example, the hill at grid coordinates 485536 on the LEAVENWORTH map could be called which of the following?

a. hill 967	b. hill 769	c. RJ 970

(c. 440, 620) (59)

FRAME 60.

Step 4. Place a sheet of lined paper along the profile line with the lines parallel to the profile line (Panel 5-14). (Graph paper may be used or uniformly spaced lines drawn on a blank sheet.) A line is needed for each contour between the values determined in step 3. Including lines for the 440 and 620 contours how many are needed for the profile? (Panel 5-14)

a. 6	b. 8	c. 10

(contour lines) (3)

FRAME 4.

A contour line stands for height above a certain level called base plane or datum. Thus, a 960-foot contour line means it is 960 feet above the ____________.

Set 5-2. DETERMINING GROUND SHAPES FROM CONTOUR LINES

(same) (22)

FRAME 23. INFORMATION FRAME.

You can determine ground shapes — the size and shapes of hills and valleys, steepness of slopes, and related terrain conditions — by studying the shapes and patterns of the contour lines. A careful examination of the contour lines on the map is therefore necessary to properly "see" the terrain in which you intend to operate. This would enable you, for example, to avoid excessively steep slopes and other hindrances to your actual travel on the ground, and to avoid locating bivouacs and vehicle parks in areas subject to flooding.

Set 5-4. COMPUTING SLOPE

(a. hill 967) (41)

FRAME 42. INFORMATION FRAME.

You will recall that when you learned about contours, you saw that contour spacing on your LEAVENWORTH map indicated the type of slope. Closely spaced contours, for example, represented a steep slope. The steepness of slopes is obviously very important in planning the movement of a unit, since steepness affects mobility, concealment, use of plunging fire, etc. In the next few frames, you will learn how to compute accurately the slopes or gradients of the ground on which your unit may have to operate.

(c. 10. The difference in elevation (620-440) is 180 feet or nine 20-foot intervals. It will require 10 lines to show these nine intervals.) (60)

FRAME 61.

Step 5. Starting with the lowest value at the bottom, label each line consecutively with its proper contour value (Panel 5-14). You will have 10 labeled lines ranging from _________ to _________.

a. 440 - 620

b. 460 - 600

c. 480 - 580

(datum (base plane)) (4)

FRAME 5.

The datum used on military maps is mean sea level (average sea level). The 960-foot contour, no matter on which map it is drawn, is always 960 feet above __________ __________ __________.

(Go on to the next frame) (23)

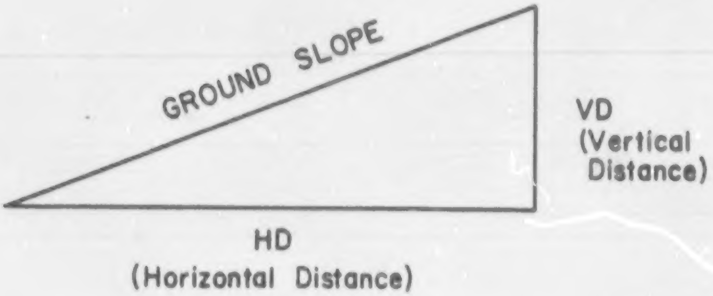
FRAME 24.

Peaks or hilltops (Panel 5-2) are easily identified because the contours close to form concentric circles, ovals, or loops. Remember, contours forming concentric loops depict ____________________.

(Go on to next frame) (42)

FRAME 43.

Ground slope is a ratio of vertical distance to horizontal distance or $\frac{\text{vertical distance}}{\text{horizontal distance}}$. This ratio expressed as a simple fraction is called a gradient. The gradient is one way of expressing __________________.



(a. 440-620) (61)

FRAME 62.

Step 6. Mark the position of the starting and finishing points (A and B) on the edge of the lined paper (Panel 5-14). (Include any of the points with known elevations, such as road junctions.) In effect, you have marked the distances between these points on the paper's edge. This corresponds to which distance between the points?

a. horizontal b. vertical

(mean sea level) (5)

FRAME 6.

On maps, the vertical distance or height above mean sea level is called elevation. The 960-foot contour, being 960 feet above mean sea level, is 960 feet in

____________________.

(hills (peaks or hilltops)) (24)

FRAME 25.

Contour lines that show a relatively low point, frequently between two hilltops, along a formation of high ground indicate a saddle (Panel 5-3). As a general rule, a ____________________ is a noticeably low spot along the crest of a high formation.

(slope) (43)

FRAME 44.

To compute gradient, the horizontal and vertical distance must always be the same units of measure such as feet, yards, or meters. When the slope is expressed as a fraction ($\frac{VD}{HD}$ in the same units), it is called a ____________.

(a. horizontal) (62)

FRAME 63.

Step 7. From the starting and finishing marks, draw perpendiculars straight down across the horizontal lines to their elevations as indicated by the spaced and labeled lines. Mark these elevations with a dot. For example, the starting point, A, (Panel 5-15) has an elevation of 538 feet. The perpendicular should be marked between the 520 and 540 lines at an elevation of __________ feet.

(elevation (Note: In mapping, elevation is height above mean sea level, whereas in artillery, elevation is a vertical angle or angular height from a horizontal plane.)) (6)

FRAME 7.

Refer again to coordinates 4152 on your LEAVENWORTH map and you will find 900 printed in brown on a contour line. This means that the 900-foot contour being 900 feet above mean sea level is 900 feet in ________________.

(saddle) (25)

FRAME 26.

A ridge is a formation of high ground, often consisting of a series of connected peaks and saddles. The ridge "line" follows the backbone, or highest points, through the formation (Panel 5-4). Contours cross the imaginary ridge "line" at right angles and turn back to parallel the ridge line. The series of connected peaks and saddles along the backbone of a formation of high ground defines a ________.

(gradient) (44)

FRAME 45.

The contour interval (vertical distance two contours) is 20 feet. The horizontal distance between the same two contours measures 100 feet. The gradient (ground slope) between these contours is $\frac{20 \text{ feet}}{100 \text{ feet}}$ or $\frac{1}{5}$. What is the gradient if the horizontal distance between the contours increases to 600 feet?

a. $\frac{1}{5}$ b. $\frac{1}{30}$ c. $\frac{1}{600}$

---

(538) (63)

FRAME 64.

Step 8. At each contour line crossing or touching the profile line, draw a perpendicular to its corresponding elevation and mark this point (Panel 5-15). The profile will cross through all the marked points and shows the __________ view of the ground (not to scale).

(elevation) (7)

FRAME 8.

Refer to grid square 2852 on your LEAVENWORTH map and you will find another contour whose height is printed in brown on the contour line. The elevation of the contour is ____________ feet.

(ridge) (26)

FRAME 27.

A protrusion or extension from a hill or ridge into lower ground is a spur. The contours follow around the spur in a U-shape with the U pointing downhill (Panel 5-4). The distinguishing characteristic of a spur is the contour pointing downhill in a ___________ shape.

a. V

b. U

c. M

562

(b. $\frac{1}{30}$. $\frac{VD}{HD} = \frac{20 \text{ feet}}{600 \text{ feet}} = \frac{1}{30}$) (45)

FRAME 46.

Slope can also be expressed as a percent or $\frac{VD}{HD} \times 100$. The $\frac{1}{30}$ gradient of the last frame equals $\frac{1}{30} \times 100$ or 3.33 percent slope. What is the percent slope of the 100-foot spacing in the previous frame?

a. 5 b. 20 c. 33

(side) (64)

FRAME 65.

Step 9. The higher points along the profile line will be the hilltops and ridges. The lower points will be the draws and depressions. Mark the positions of each one and draw the perpendiculars across the horizontal lines to their elevation points on the ruled spaces. (See Panel 5-16.) The profile will change direction (up to down or vice versa) at these critical points which define the ________________ and ________________ points along the profile.

576

(1000) (8)

FRAME 9. INFORMATION FRAME.

Refer to grid square 2852 again. You see that there are many other contour lines besides the one you found to be 1000 feet in elevation. You will now learn how these other contour lines show changes in elevations. Each of these contour lines, though not numbered, also represents a specific ground elevation. On the LEAVENWORTH map, each change of elevation of 20 feet is shown by a solid contour line.

(U) (27)

FRAME 28.

As contour lines approach draws (beds of running or dry streams), they turn upstream and run along the sides until they cross. Contours cross draws and turn back in a characteristic V shape with the V pointed upstream (Panel 5-5). To identify a draw, you must locate the upstream pointing of the ______________ contours.

a. V-shape. b. U-shape. c. M-shape.

(b. 20. $\frac{20}{100} \times 100 = 20$ percent slope) (46)

FRAME 47.

Refer to your LEAVENWORTH map. You want to find the percent of slope of the ground between the dirt road junction at 482534 and hilltop 967 to the northeast. You must determine first the ________________ distance and the ________________ distance between the points.

(higher, lower) (65)

FRAME 66.

Step 10. Connect all marked points with a smooth natural curve. (See Panel 5-17.) The curve will change direction at the perpendicular lines indicating high and low points. At the hilltops (ridges) the curve will be smooth and rounded, while in the draws it will turn back in the form of a __________ shape.

a. U b. V c. M

(Go on to next frame) (9)

FRAME 10.

Look at Panel 5-1. It shows a horizontal plane cutting through a hill. The line marking all the points where this plane cuts the hill is at the same elevation. It is called a ________________ line.

(a. V-shape) (28)

FRAME 29.

In mountains or hills of higher elevations, draws are narrow but as they reach lower elevations, they become larger and are often wide enough to permit at least limited maneuvering of a military unit. These wide portions are called valleys (Panel 5-5). The ________________ retain the V-shape characteristics of a draw.

(vertical, horizontal) (47)

FRAME 48.

Use the edge of a sheet of paper to measure the horizontal distance. Transfer this measurement to the bar scale (in YARDS) and read the number of yards. Multiply the yard reading by 3 and you have the horizontal distance in feet. What is the approximate distance?

a. 85 b. 500 c. 1400

(b. V) (66)

FRAME 67.

For a hasty profile, only the contours identifying the high and low points are plotted. (See Panel 5-18.) The remainder of the profile is completed by joining these points. The high and low points identify which map features?

a. ridges and draws b. road crossings c. woods lines (contour) (10)

FRAME 11.

A contour line drawn above or below the first one would be at a different elevation. The contour interval is the difference in ____________ between adjacent contour lines. If 1000-foot and 980-foot contours are adjacent contours on a map, the contour interval is ________ feet. (Panel 5-1) The next lower contour line going down towards a stream or draw would be ____________.

(valleys) (29)

FRAME 30.

A large hole, sink, or depression in the ground (Panel 5-6) is shown by a closed loop contour. Ticks are added inside the loop to indicate that the lower ground is inside the contour. When ticks appear along a contour, they indicate that the ground on that side of the contour is ____________.

(1400. The distance measures about 470 yards on the bar scale and therefore approximately 1400 feet) (48)

FRAME 49.

For the vertical distance, start with the road junction. It falls halfway between the 900- and the 920-foot contours, or at __________ feet.

(a. ridges and draws) (67)

FRAME 68.

The profiles just completed can be exaggerated in a vertical direction depending upon the spacing between the parallel horizontal lines. This exaggeration may be varied to suit any purpose by changing the __________ of the lines.

(elevation, 20 (1000 - 980 (difference in elevation) equals 20 feet)(960)) (11)

FRAME 12.

No matter how far apart two adjacent contours are drawn on the map, the contour interval defines the difference in ________________ between these two lines.

(lower) (30)

FRAME 31.

Roads and railroads are cut through hills and spurs and are built on fills across draws and low places (Panel 5-7). On a map, cuts are indicated by solid brown lines that are parallel to adjacent roads, railroads, or other manmade features. Fills are also indicated by ________________ lines adjacent to roads, railroads, or other ________________ features but have ticks added to indicate the direction of lower ground.

570

(910) (49)

FRAME 50.

The measured elevation above sea level of the top of the hill (967 feet) is shown on the map. To find how high the hill is above the surrounding terrain (vertical distance), subtract the elevation of the bottom of the slope at the crossroads (910 feet) from the elevation of the top of the hill (967 feet). The vertical distance is ______________ feet.

Set 5-6. USE OF PROFILE TO SHOW AREAS OF CONCEALMENT

(spacing) (68)

FRAME 69.

Profiles are used to determine where friendly and enemy forces are intervisible (can see each other). The high points will block the view or line of sight, and anything behind the ____________ points will not be seen.

584

571

(elevation) (12)

FRAME 13.

Refer to the marginal information (bottom center) of the LEAVENWORTH map. What is the contour interval for this map?

a. 5 feet b. 10 feet c. 20 feet

Set 5-3. SLOPE

(parallel) (manmade) (31)

FRAME 32.

The horizontal spacing between two adjacent contours represents the horizontal distance between the two elevations on the ground. (See Panel 5-8.) The slope of the ground between two contours is "pictured" by the contour interval (vertical distance) and the spacing or ______________ distance.

585

(57 feet) (50)

FRAME 51.

The vertical distance from the hilltop to crossroads is 57 feet. The horizontal distance between the hill and crossroads you found to be 1400 feet. The slope of the hillside is $\frac{VD}{HD}$, or $\frac{57 \text{ feet}}{1400 \text{ feet}}$. What is the percent slope?

a. $\frac{1}{25}$ b. 2.5 c. 4

(high) (69)

FRAME 70.

Refer to Panel 5-12. Profile A has an observation point at the left with the line of sight drawn over each intervening high point. The shaded areas behind the hills and under the line of sight are ____________ (since a line of sight is always a straight line).

a. visible b. invisible

(c. 20 feet) (13)

FRAME 14.

Each plane represents contours at a different elevation, and the distance or interval between planes is the ______________ ______________ (Panel 5-1).

(horizontal) (32)

FRAME 33.

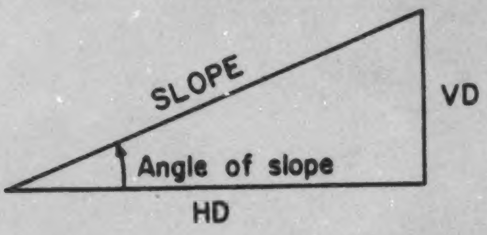
Contour patterns indicate steepness of ground slope. (Panel 5-9) Widely spaced contours indicate a gentle ____________. Steep slope is indicated by ________ spaced contours.

(c. 4. $\frac{57}{1400} \times 100 = 4$ percent) (51)

FRAME 52.

Slope can also be expressed as an angle or "degree of slope" (see sketch). The gradient converted to a decimal is the tangent of the slope angle. For example, $\frac{1}{5} = 0.2$, expressed as a decimal. This value, 0.2, is the tangent of the slope angle or ___________ of slope and is found in a table of trigonometric functions.

The tangent of the angle of slope $= \frac{\text{side opposite}}{\text{side adjacent}} = \frac{VD}{HD}$.



(side opposite)

(side adjacent)

(b. invisible) (70)

FRAME 71.

The shaded areas (Panel 5-12) also can tell you heights of objects which will be concealed. You measure these heights from the contour line values on your profile. Shaded areas show the _______________ of objects that can be concealed.

575

(contour interval) (14)

FRAME 15.

Contour lines are drawn as brown lines on the map. Every fifth line (starting from zero elevation) is made heavier and is called an index contour. Printing the ______________ contours as heavier lines makes the map easier to read.

(slope, closely) (33)

FRAME 34.

Referring to your LEAVENWORTH map, grid square 2849 would appear to have ______________ slopes compared to the slope in most of the area in grid square 2949.

(degree) (52)

FRAME 53.

If you consult a table of trigonometric functions, you find that .2 is the tangent of 11° 20′. Approximate slope angle or degree of slope can also be calculated without the use of the tables. Multiply the gradient by 57.3 and the result is the approximate angle of slope in degrees. For example, $\frac{1}{30}$ gradient = $\frac{1}{30} \times 57.3 = 1.9$ or 2° of slope when rounded off. What is the approximate slope in degrees if the gradient is $\frac{1}{5}$?

a. 5 b. 8½ c. 11½

(heights) (71)

FRAME 72.

The extent of the hidden area (in a horizontal direction) is determined by transferring the shaded area points back to the map. Several profiles radiating from the observation point will define the ______________ of the area hidden (Panel 5-12).

(index) (15)

FRAME 16.

As you have seen, the LEAVENWORTH map has a contour interval of 20 feet which indicates a difference in height of 20 feet between contours. You note from your map that the index contours (every fifth contour) are the ________ foot contour lines.

(gentle) (34)

FRAME 35.

Evenly spaced contours indicate a uniform slope (Panel 5-10). If they are closely spaced, they represent a ______________ uniform slope; if widely spaced, a ______________ uniform slope.

578

(c. 11½. $\frac{1}{5} \times 57.3 = 11\frac{1}{2}$ degrees of slope. Note: This method is reasonably accurate up to 20 degrees of slope.) (53)

FRAME 54.

Slope may be rising (up) or falling (down), and a plus or minus, respectively, is added. The slope of a road is 3 percent from elevation 500 to elevation 580. How is this expressed?

a. +3 percent b. –3 percent

(extent) (72)

FRAME 73.

Using the heights of the hidden area (defilade) from the profile, a commander can select the best route to cover the movement of troops and equipment. On profile A, Panel 5-12, how many of the three draws will safely hide vehicles and troops?

a. 1 b. 2 c. 3

592

(100) (16)

FRAME 17.

Again on your LEAVENWORTH map, what are the two index contours shown in grid square 2852 and grid square 2850 respectively?

(steep, gentle) (35)

FRAME 36.

Change in contour spacing along a slope also indicates a type of slope. Closely spaced contours (steep slope) at the top and wider spacing (gentle slope) at the bottom (A, Panel 5-10) represent a __________________ slope. Wide spacing (gentle slope) on top and close spacing (steep slope) near the bottom (B, Panel 5-10), indicate a __________________ slope.

Set 5-5. CONSTRUCTING A PROFILE

(a. +3 percent. This slope is up or rising from 500 to 580. In the other direction, the slope from 580 to 500 is minus (down or falling) (54)

FRAME 55. INFORMATION FRAME.

A profile or side view (cross section) of the ground along a selected line or direction can be used to determine where friendly and enemy forces are intervisible (can see each other). Certain high points might block the view or line of sight from one point to another. The next few frames will show you how to construct a profile of the ground from the contours shown on your map for the same area (see Panel 5-12).

Set 5-7. ADDITIONAL MAP TECHNIQUES WHICH SHOW RELIEF

(b. 2) (73)

FRAME 74.

Hachures are short brown lines or ticks drawn in a pattern to represent land forms (relief). The length and spacing of the ticks create a picture of the slopes, but do not indicate amounts. Hachures, added to contour maps, show detail too small to be indicated by the contour interval. What other brown line symbols do hachures replace in this case?

a. index contours b. intermittent streams c. supplementary contours

581

(1000, 1100) (17)

FRAME 18.

The four contour lines between index contours are called intermediate contours. The brown line is thinner than the index contour, and usually elevations are not shown on these lines. The thin lines between index contours are called the ________________ contours.

(concave, convex) (36)

FRAME 37.

As the ground slope increases in steepness, the contours appear closer together. On a vertical slope or cliff, there is no horizontal spacing between contours (Panel 5-11). They appear as a single line. When contours on a map run into a single line, the ground formation is a ________________.

(Go on to the next frame) (55)

FRAME 56.

A profile can be constructed between any two points on a contour map. For example, the slopes of a road between road junction 538 A and road junction 520 B in Panel 5-13 are required. The profile along this line (Panel 5-13) will show all the __________________.

(supplementary contours) (74)

FRAME 75.

Relief may also be indicated on maps by layer tinting, shaded relief, and form lines. These methods are described in FM 21-26. Like hachures, these methods indicate only specific qualities of the land forms, such as size or extent. Measurements of the relief, such as slopes and elevation differences, cannot be made as with __________________.

(intermediate) (18)

FRAME 19.

In relatively flat terrain areas, relief changes are gradual so that the contour interval (20 feet for LEAVENWORTH map) may be too great to show critical landforms. Supplementary contours are added in these areas only, to show the changes of ______________ than 20 feet. When ______________ contours are used, an explanatory note is placed in the margin.

Turn back to bottom of page 5-1 for frame 20

(cliff) (37)

FRAME 38.

Contours also provide elevation information for the locations on a map. A 960-foot contour passes through all points which are 960 feet in elevation. If the 960 contour passes through a road junction, the elevation of the road junction is __________________.

Turn back to top of page 5-2 for frame 39

(slopes) (56)

FRAME 57.

Frames 5-57 through 5-67 discuss the steps in constructing a profile. Refer to Panel 5-13 in studying the steps to follow.

Step 1. Connect the two points, A and B, with a straight line (Panel 5-13). This is the profile line. The side view of the slopes will be shown along this ________________ line.

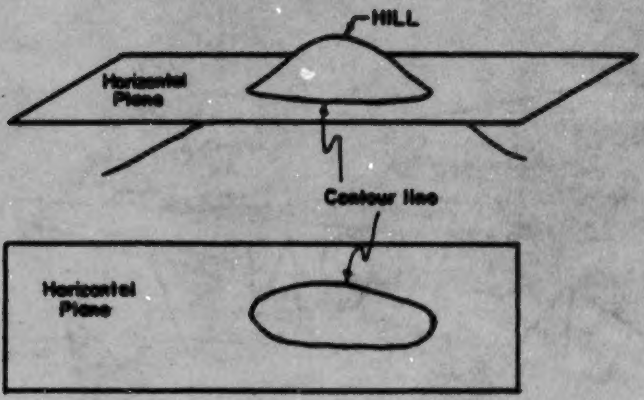
Turn back to bottom of page 5-2 for frame 58

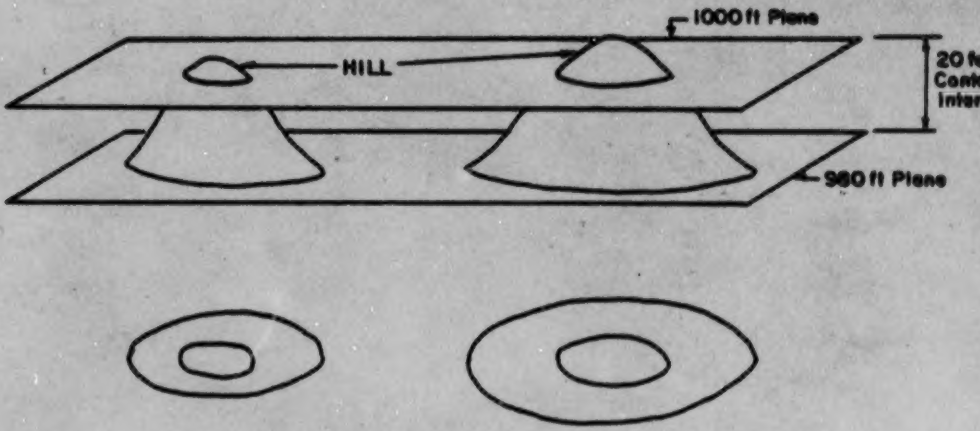
(contours) (75)

END OF FRAMES FOR PART V

PANEL 5-1

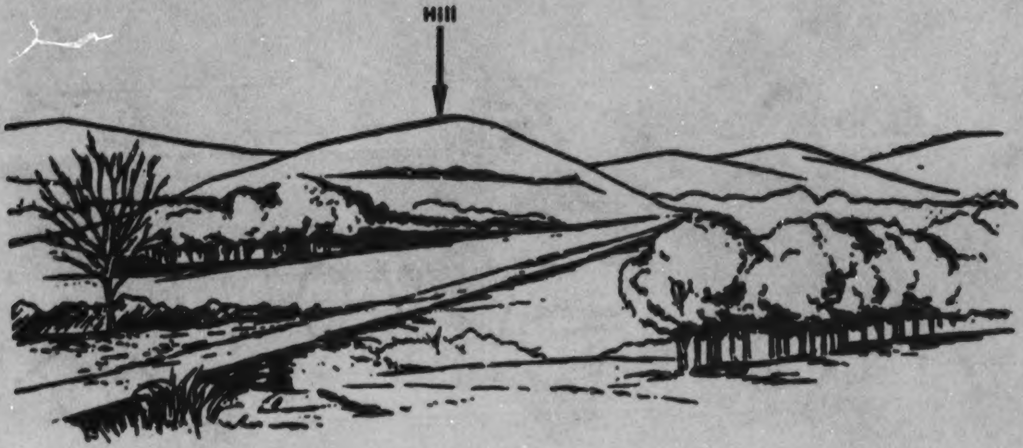
CONTOUR LINES AND INTERVALS

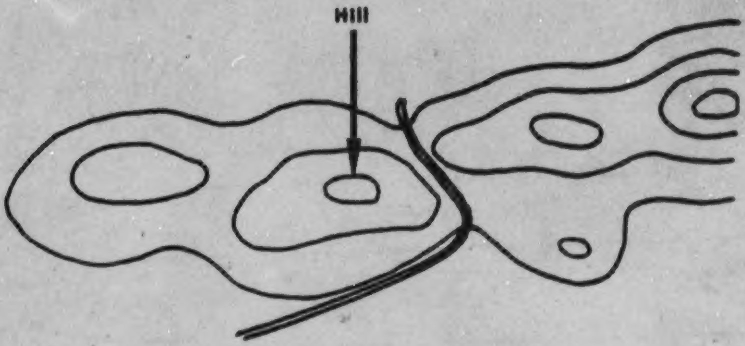

HILL
Horizontal Plane
Contour line
Horizontal Plane


1000 ft Plane
HILL
20 feet Contour Interval
980 ft Plane

586

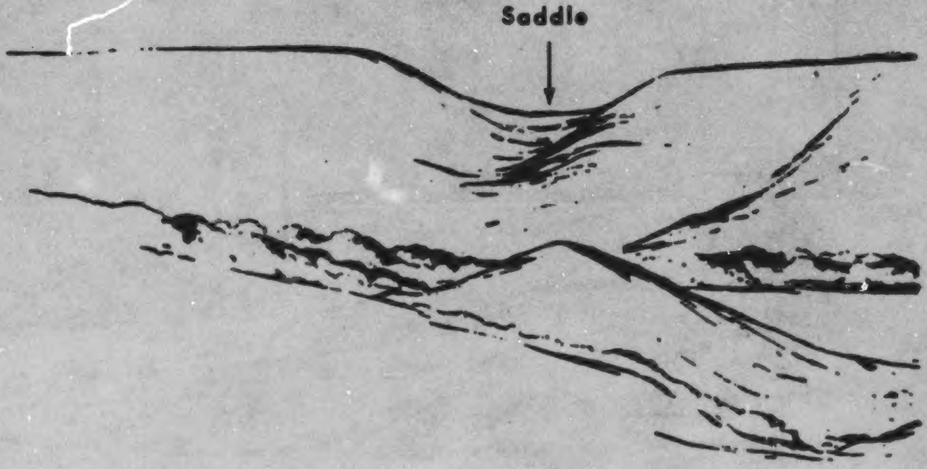
PANEL 5-2 — HILL

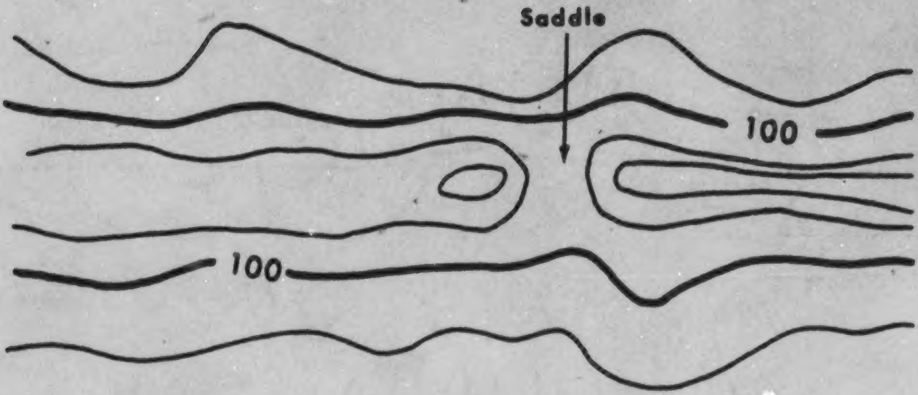




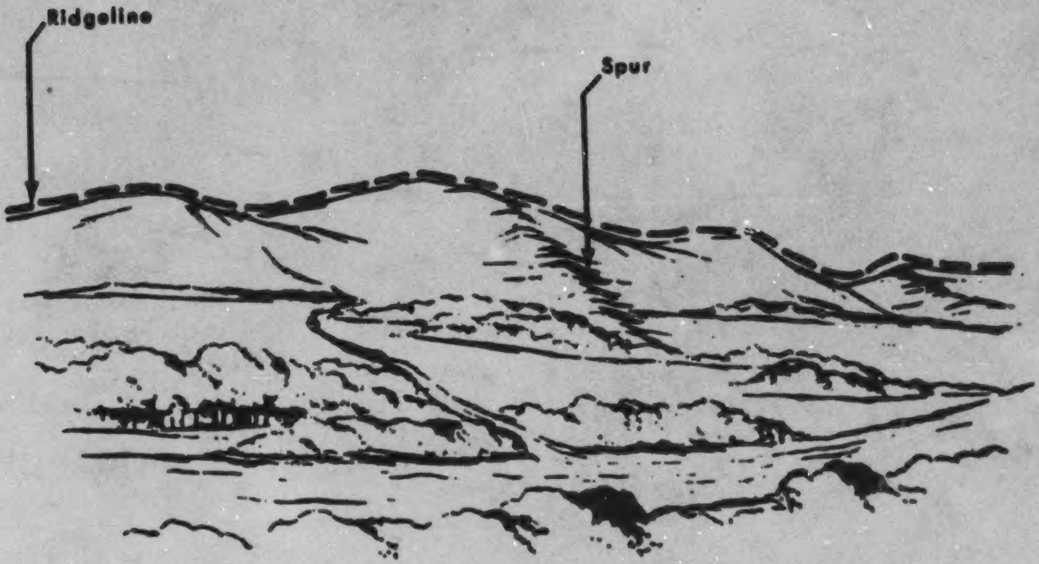
600

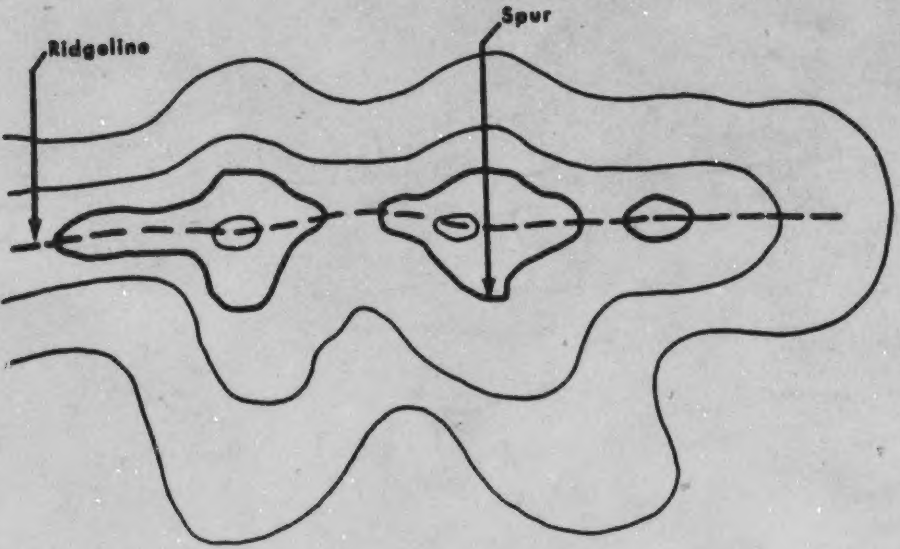
PANEL 5-3 — SADDLE



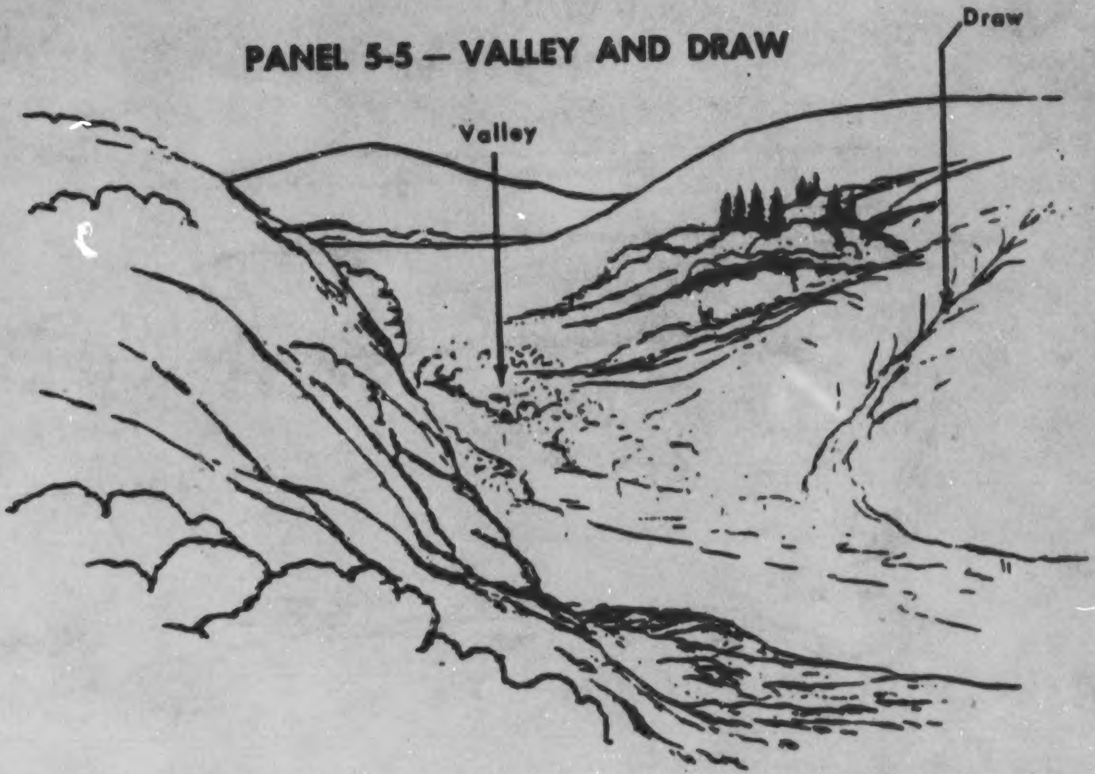

Saddle
100
100

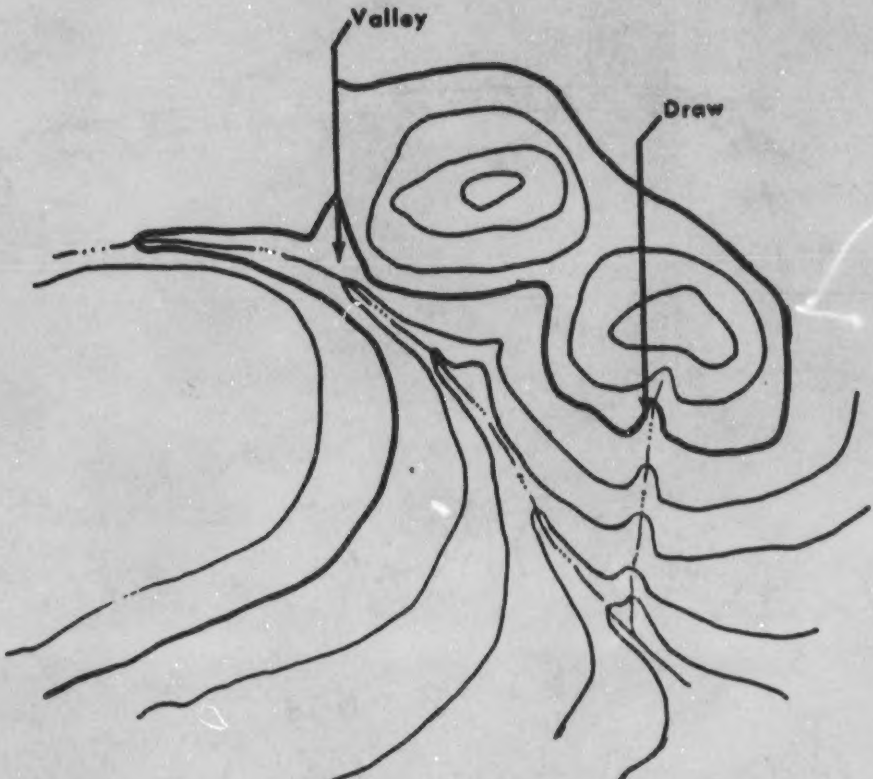
PANEL 5-4 — RIDGE AND SPUR


Ridgeline
Spur

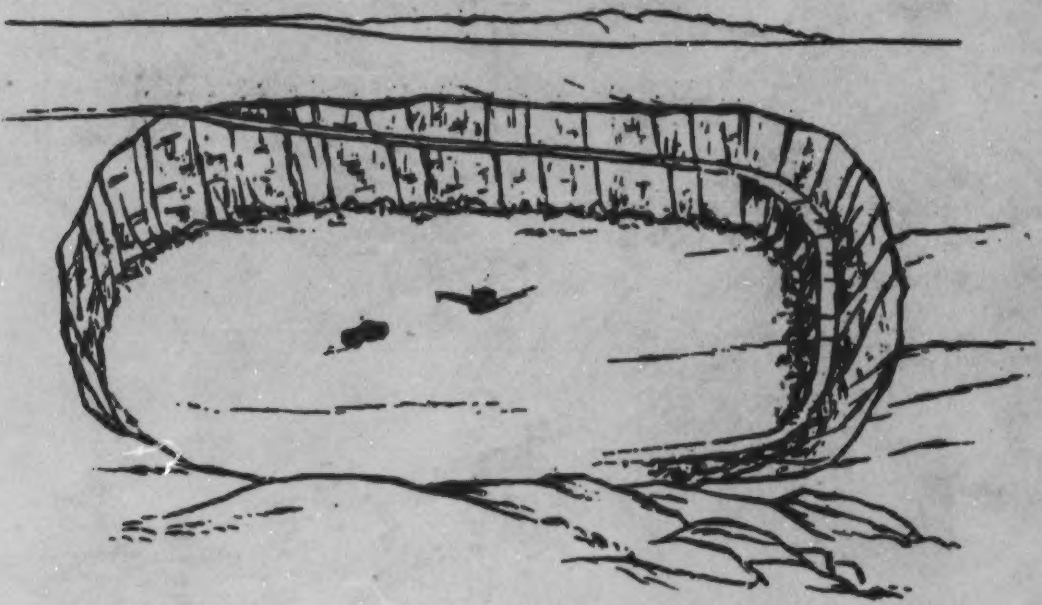

Spur
Ridgeline

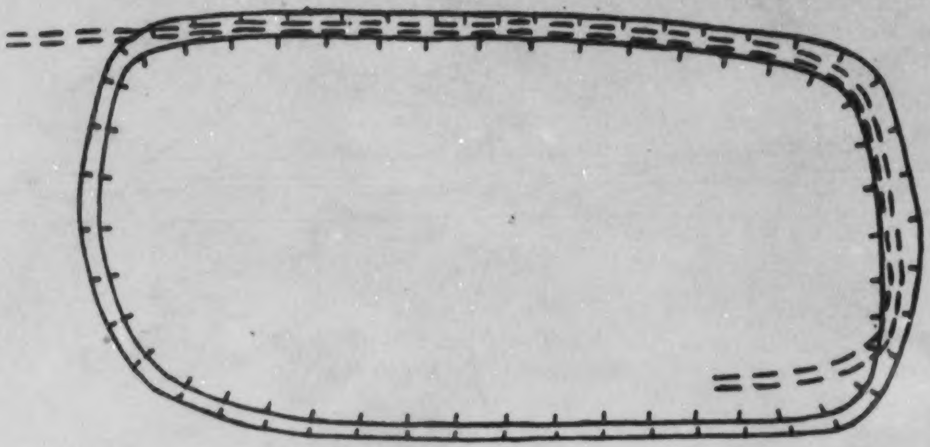
PANEL 5-5 — VALLEY AND DRAW


Draw
Valley


Valley
Draw

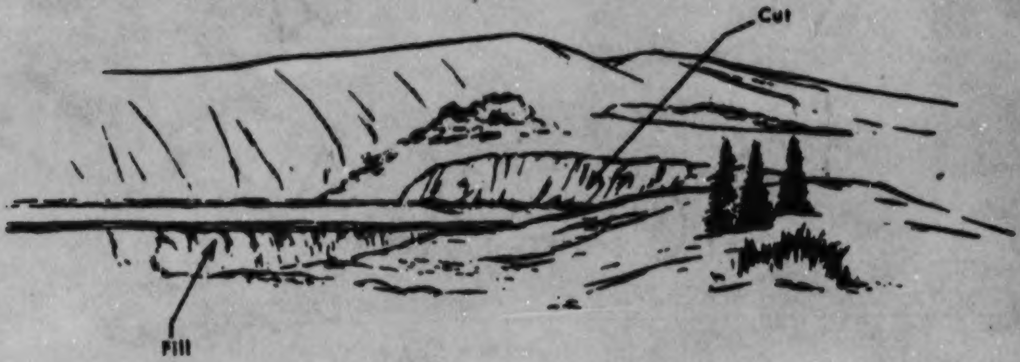
PANEL 5-6 — DEPRESSION

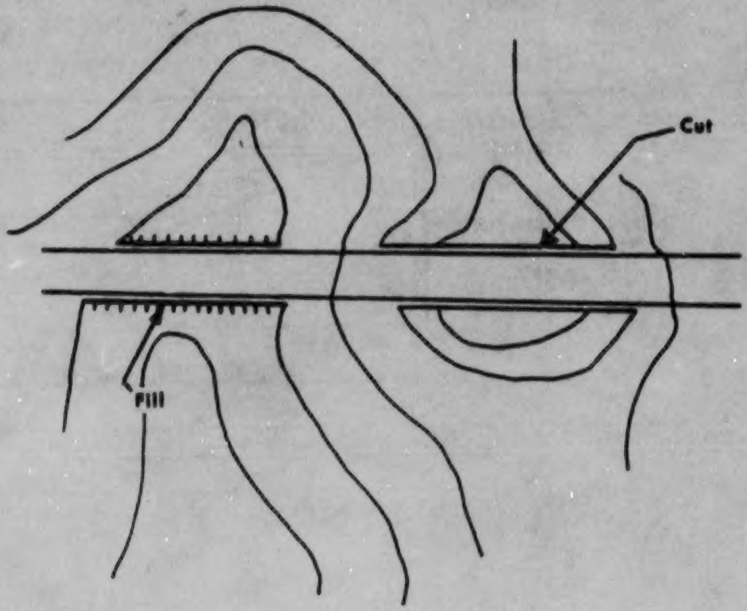




591

PANEL 5-7 CUT AND FILL

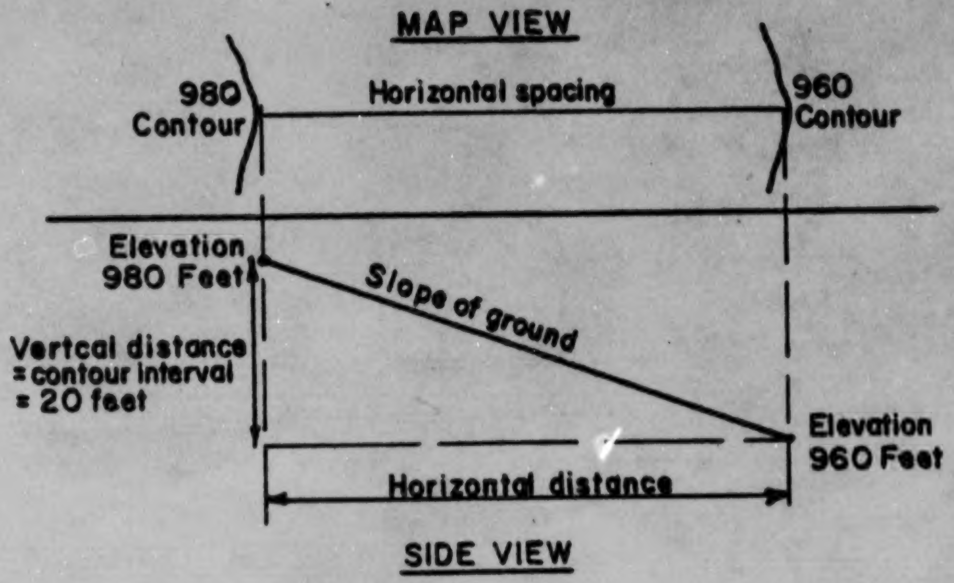




592

PANEL 5-8

CONTOUR LINE AND ACTUAL SLOPE OF THE GROUND

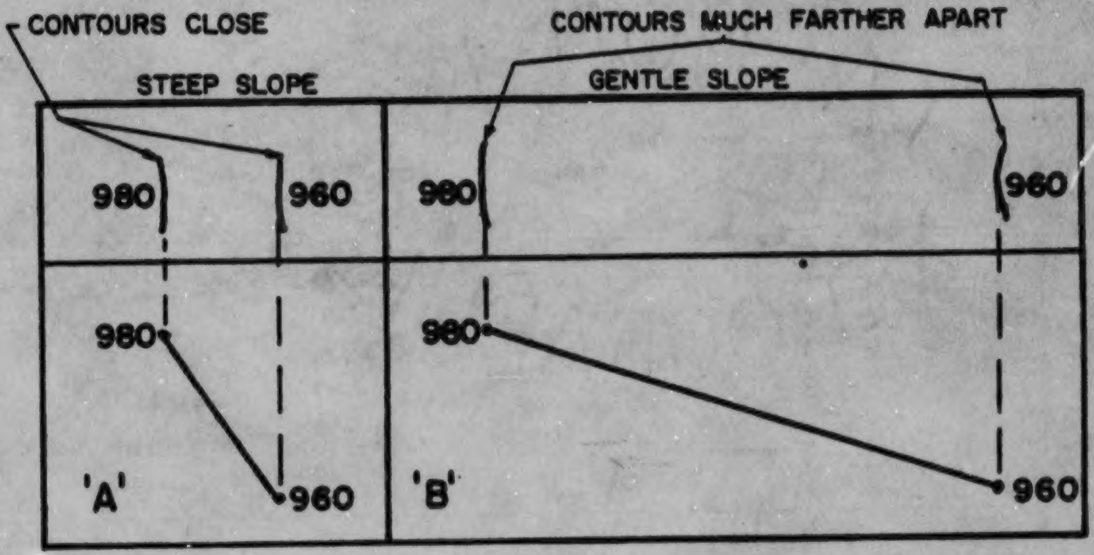

MAP VIEW
980 Contour
Horizontal spacing
960 Contour
Elevation 980 Feet
Slope of ground
Vertcal distance = contour interval = 20 feet
Elevation 960 Feet
Horizontal distance
SIDE VIEW

606

593

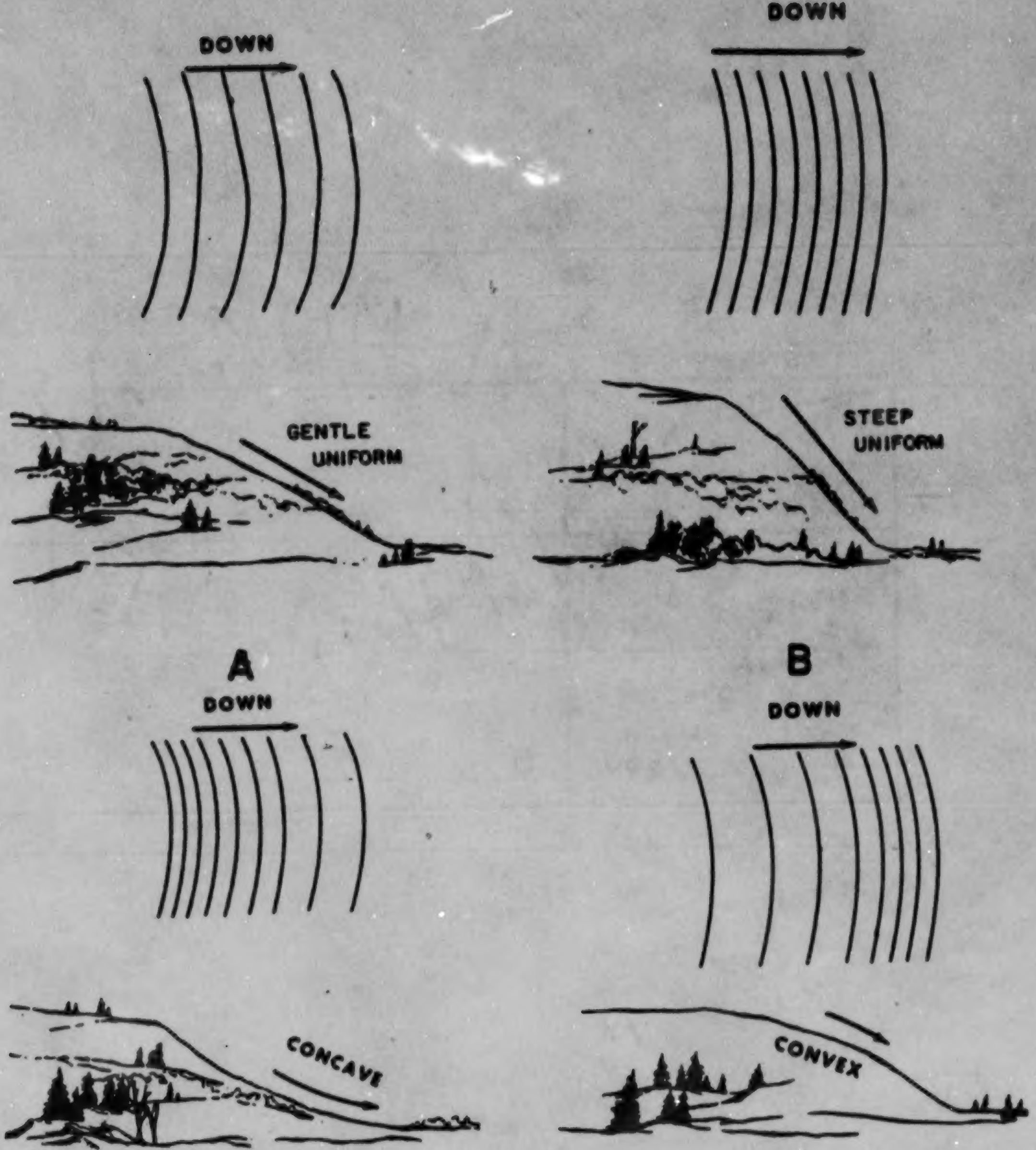
PANEL 5-9

CONTOUR SPACING AND SLOPE OF THE GROUND

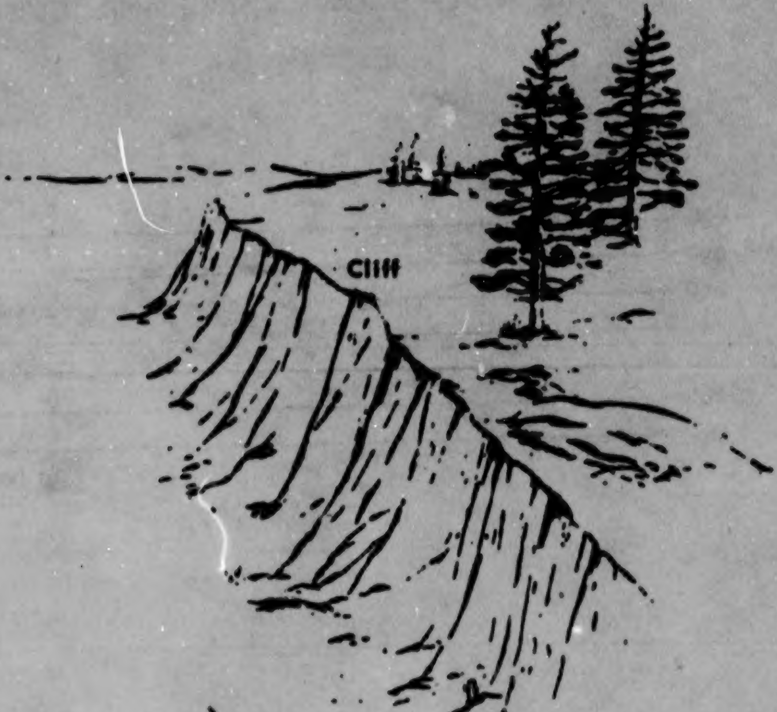

CONTOURS CLOSE
STEEP SLOPE
CONTOURS MUCH FARTHER APART
GENTLE SLOPE
980
960
980
960
980
960
980
960
'A'
'B'

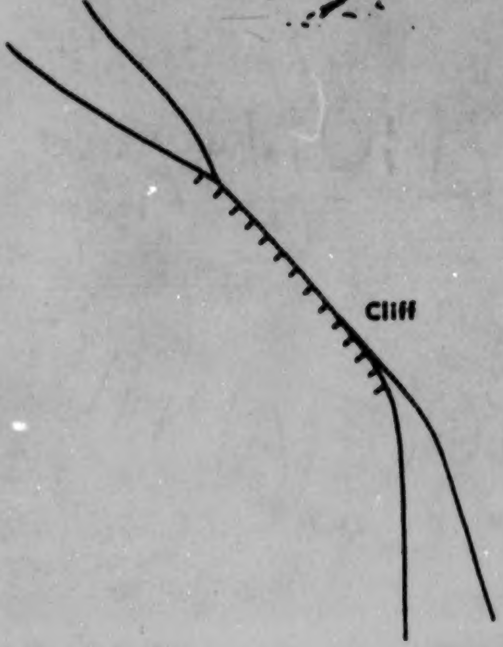
607

PANEL 5-10 — SLOPES


DOWN
GENTLE UNIFORM
DOWN
STEEP UNIFORM
A
B
DOWN
CONCAVE
DOWN
CONVEX

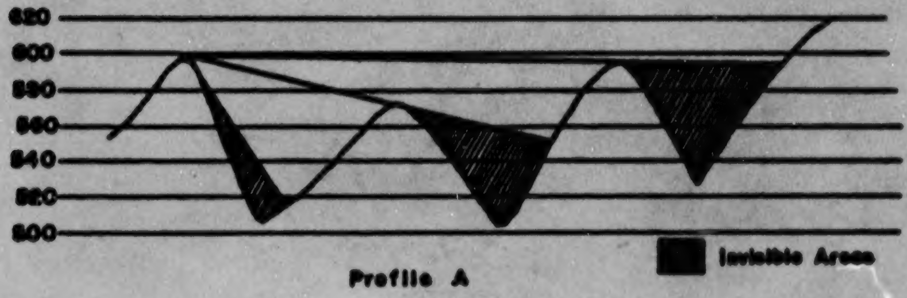
PANEL 5-11 CLIFF

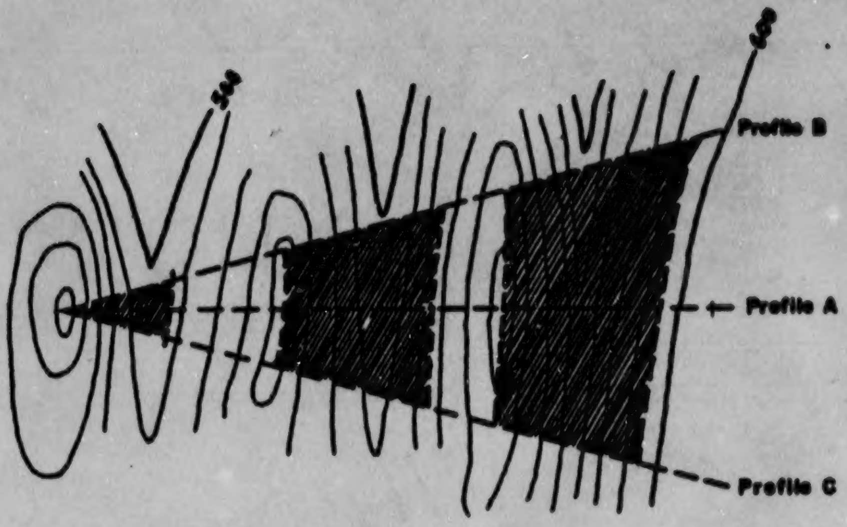




PANEL 5-12

PROFILE WHICH SHOWS VISIBLE AND INVISIBLE AREAS



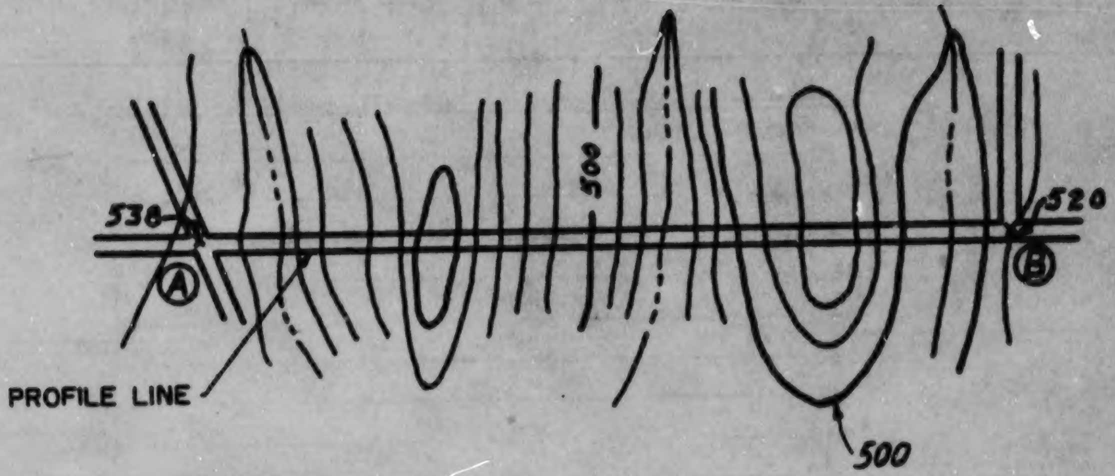

580
600
Profile B
Profile A
Profile C

INVISIBLE AREAS TRANSFERRED TO MAP

NOTE: Intervisibility cannot be determined from a profile based on contours alone. Heights of trees and other intervening objects must be taken into account.

PANEL 5-13

CONSTRUCTING A PROFILE

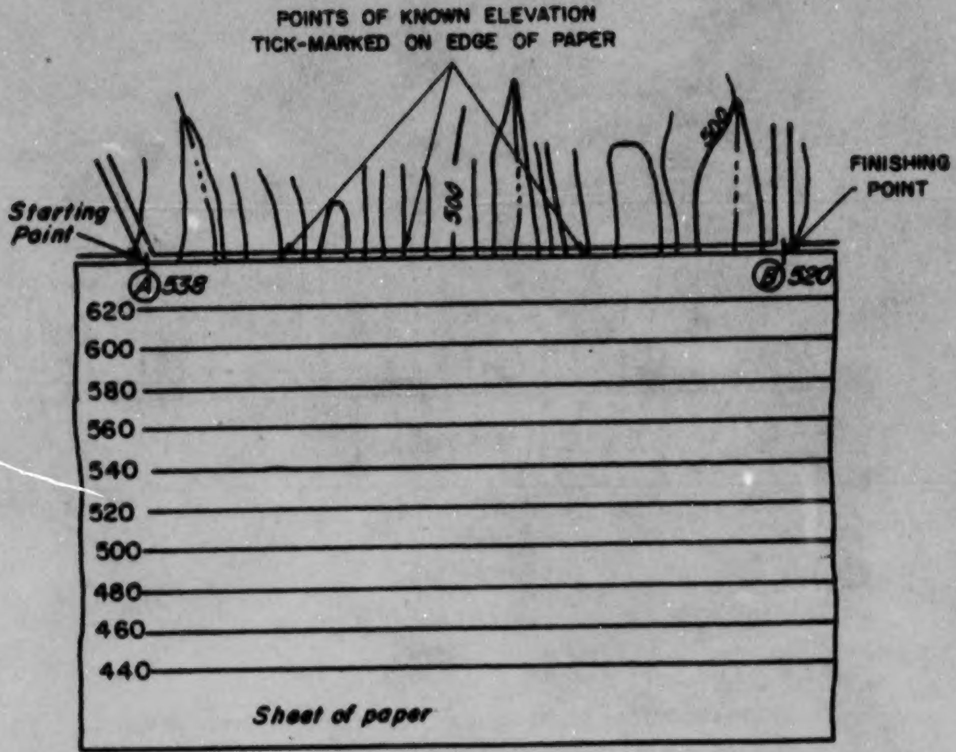

538
Ⓐ
PROFILE LINE
500
500
520
Ⓑ

Slopes (contours) between two points (road junctions) on a road. The straight road can be used as the profile line.

598

PANEL 5-14

CONSTRUCTING A PROFILE (Continued)


POINTS OF KNOWN ELEVATION
TICK-MARKED ON EDGE OF PAPER
Starting Point
FINISHING POINT
500
500
Ⓐ 538
Ⓑ 520
620
600
580
560
540
520
500
480
460
440
Sheet of paper

Place sheet of lined paper along profile line and mark points of known elevation.

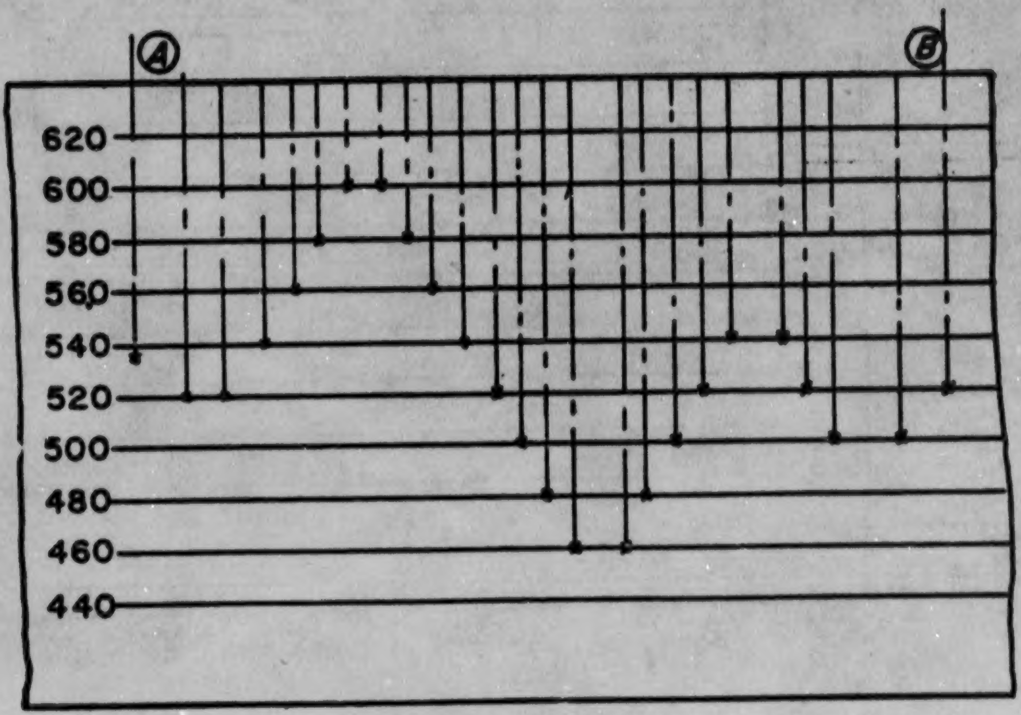
Any paper with evenly-spaced horizontal lines, such as graph or notebook paper, may be used. The wider the spacing of the lines, the greater the vertical exaggeration in the profile. However, the indication of intervisibility along a line of sight is not affected by the vertical exaggeration in the profile.

612

599

PANEL 5-15

CONSTRUCTING A PROFILE (Continued)


A
B
620
600
580
560
540
520
500
480
460
440

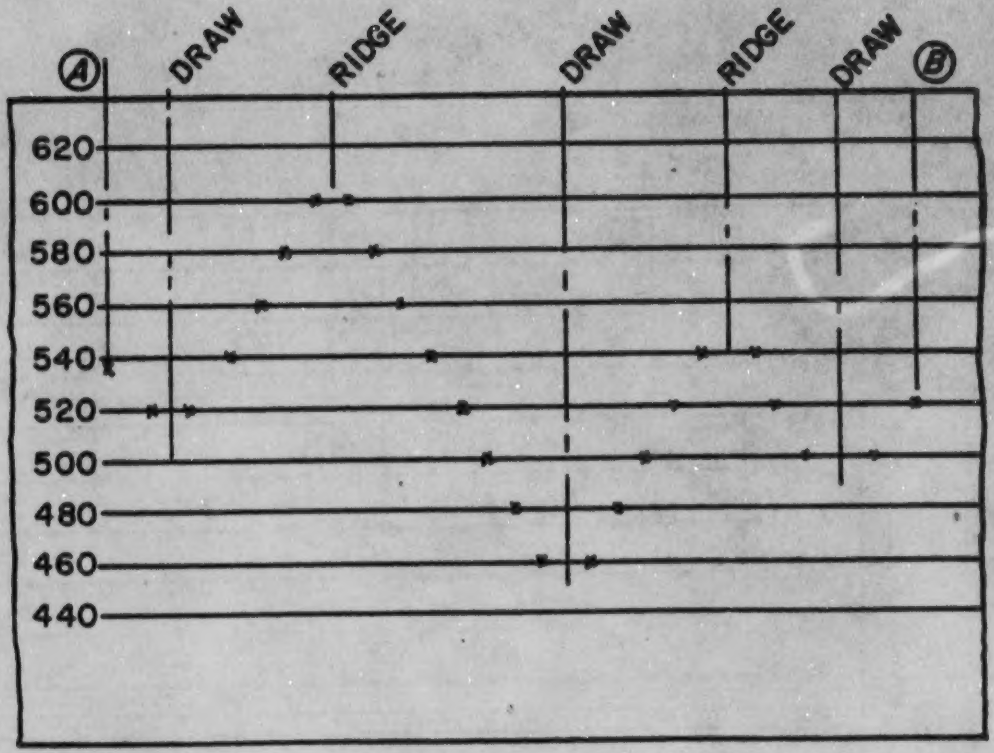
Draw perpendiculars down across horizontal lines for each marked point

613

600

PANEL 5-16

CONSTRUCTING A PROFILE (Continued)

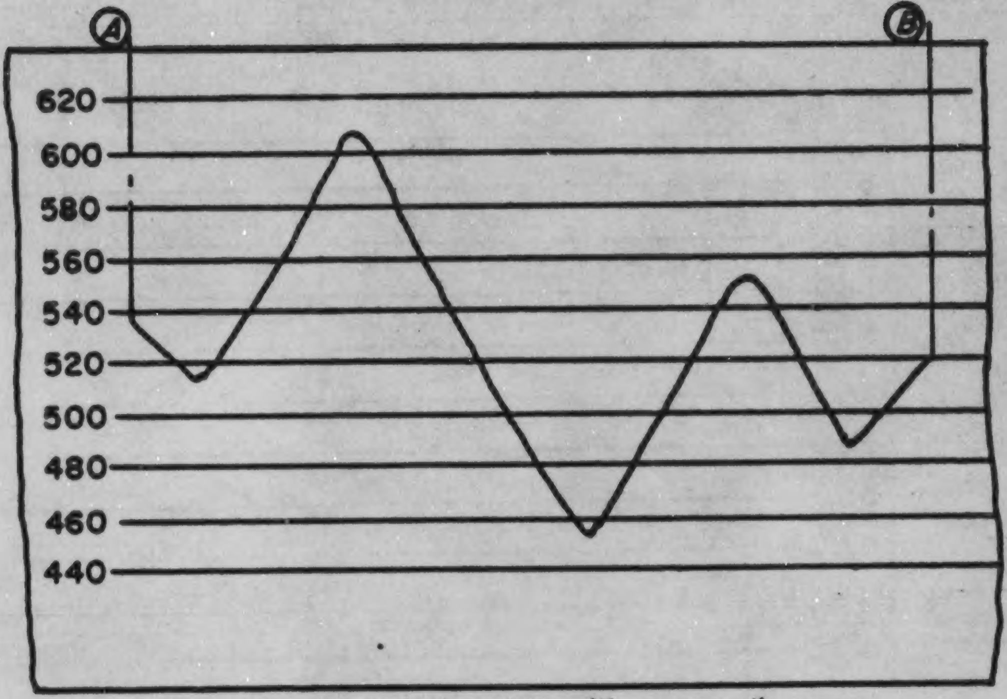

A
DRAW
RIDGE
DRAW
RIDGE
DRAW
B
620
600
580
560
540
520
500
480
460
440

Identify the high and low points along the profile

614

PANEL 5-17

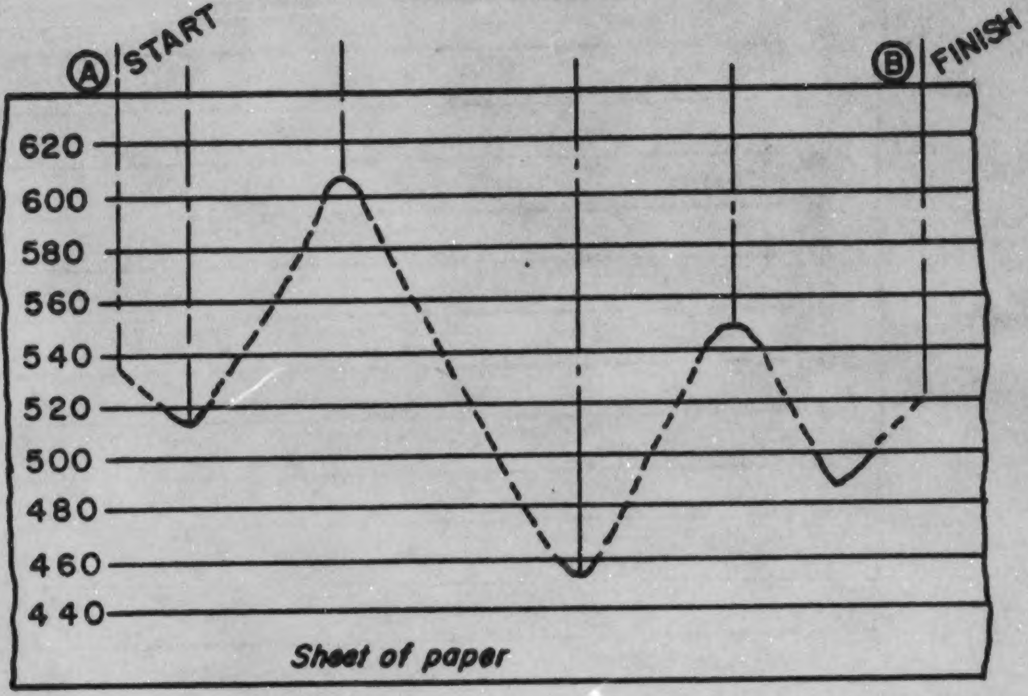
CONSTRUCTING A PROFILE (Continued)



Connect all marked points with a smooth curve

PANEL 5-18

CONSTRUCTING A HASTY PROFILE


Ⓐ START
Ⓑ FINISH
620
600
580
560
540
520
500
480
460
440
Sheet of paper

Plot only the contours identifying the high and low points.

PART VI

MAP SUPPLEMENTS AND SUBSTITUTES

FRAME 1. INFORMATION FRAME.

If no maps are available for an area of operation and there is not enough time to prepare them, map substitutes must be used instead. If there are maps, but they are out-of-date or incomplete, map supplements are needed to give more or newer information. Map supplements and substitutes may be single photographs, photomosaics, photomaps, pictomaps, overlays, or special military sketch maps. The following frames discuss the different kinds of map supplements and substitutes.

(orient) (31)

FRAME 32.

As you learned in Part IV, there are three kinds of north on a map: true, grid, and magnetic. Any of these norths can be transferred from map to photo, but magnetic north is the most commonly used direction on photos. The north line usually plotted on a photo shows the direction of ________________ north.

(hangar) (62)

FRAME 63.

Some or all of the five recognition factors may be used to identify objects on a photograph. For example, you look at a small (size), round (shape), gray (tone), object that looks like a farm silo, a haystack, or a water tank. You still have two of the five factors to consider, ____________, and ____________ ____________ ____________ ____________ ____________.

(photographic) (93)

FRAME 94.

Refer again to the Fort Belvoir pictomap, grid squares 1285 and 1385. Notice that large important buildings are shown by red symbols, drawn the same size and shape as the actual photo image. Many smaller buildings which are either isolated or not part of a regular pattern are also shown in red because their photo images might not show up through the colors of the pictomap. Thus, buildings may be shown either by their photo images or by the same symbols used on ____________ ____________.

(Go on to next frame) (1)

Set 6-1. TYPES OF PHOTOGRAPHS

FRAME 2.

An aerial photograph is taken by a camera mounted in an aircraft flying above the earth's surface. Thus, a photograph taken from an aircraft is called an ________________ photograph.

(magnetic) (32)

FRAME 33.

To plot the magnetic north prong on the photo, it must first be constructed on the map. Draw an angle from a north-south grid line, the value of the G-M angle given in the declination diagram in the lower margin of the map. Be sure to use the value of the angle, rather than the plotted diagram, which may be exaggerated for clarity. The G-M angle is plotted from a ________________-________________ grid line on the map.

(shadow, relation to other nearby features) (63)

FRAME 64.

Consider the relation of the small, round, grayish object to other nearby features. Near a group of farm buildings, it might be a silo or a haystack; near a railroad track, it might be a water tank. This leaves one more factor, ________ ________________, to consider.

(topographic maps) (94)

FRAME 95.

As you have already learned, contours are shown in black on a pictomap, instead of the brown used on conventional maps. But they are read and interpreted in the same way on a pictomap as on a topographic map. Refer to grid square 1282. The contours along the shoreline are close together. Would you describe this slope as steep or gentle?

(aerial) (2)

FRAME 3.

A photograph can be taken, processed, and distributed in hours while a topographic map takes much longer to produce. What is one advantage of the aerial photograph over a topographic map?

a. quicker to produce

b. larger

c. shows contours better

(north-south) (33)

FRAME 34.

With the photo image correctly alined with the map features, draw a line on the photo parallel to the direction of magnetic north on the map. Label this line with the half-arrow used for magnetic north. This line is used to indicate the ____________________ north direction on the photograph.

(shadow) (64)

FRAME 65.

Shadows present a side view of the object. On a vertical aerial photograph, the overhead view of an object is often unfamiliar. The shadow of an object reveals the more familiar outline of its sides, aiding in its recognition. Also, since the taller the object, the longer its shadow, we can establish the relative height of an object, often the only way to distinguish it from another of similar shape. On any aerial photo, the longer the shadow cast, the ____________________ the object.

(steep) (95)

FRAME 96.

Pictomaps are usually prepared at a larger scale than standard topographic maps because the photo image shows up better at larger scales. The scale of the Fort Belvoir and Vicinity Special Map is ____________________.

(a. quicker to produce) (3)

FRAME 4.

When the camera is pointed straight down (vertically) toward the earth, it takes a vertical photograph (Panel 6-1). Tilted at an angle to the vertical, it takes an oblique photograph. What determines whether an aerial photograph is vertical or oblique?

a. altitude of the plane
b. size of the camera lens
c. tilt of the camera axis

(magnetic) (34)

FRAME 35.

Once the magnetic north direction line is plotted on the photograph, it can be easily oriented to the ground with the aid of a magnetic compass. Place the line of sight of the compass on the magnetic north line drawn on the photo, and turn photo and compass until the compass north arrow coincides with the north line drawn on the photo. The magnetic north line on the photo is now oriented to the ground ______________ ______________ direction.

(taller) (65)

FRAME 66.

On a photo you note, in the middle of a field near a farm house, a round object which casts a short shadow. You recognize it as a haystack. Close to the farmhouse is another round object which casts a shadow several times as long. This object is ________________ than the haystack. Its ________________ to the farmhouse would indicate that it is a silo.

(1:25,000) (96)

FRAME 97.

Your map scales and protractor can be used with a pictomap just as with a topographic map. When you want to determine the coordinates of a point on the Fort Belvoir pictomap, which of the map scales would you use?

a. $\frac{1}{25,000}$ b. $\frac{1}{50,000}$

(c. tilt of the camera axis) (4)

FRAME 5.

If the camera is tilted enough, the earth's horizon will appear in the photograph (Panel 6-2). This is called a high oblique. When the camera is not angled enough to show the horizon, the photograph is a low oblique (Panel 6-3). On a high oblique photo, the ____________________ shows on the photograph.

(magnetic north) (35)

FRAME 36.

If north on the photo and on the ground agree, ALL ______________ agree.

(taller, relation) (66)

FRAME 67.

Using information from the previous frames, you recognized the silo by its size (small), ______________ (round), tone (gray), ______________ (height), and ______________ to other nearby features.

($\frac{1}{25,000}$) (97)

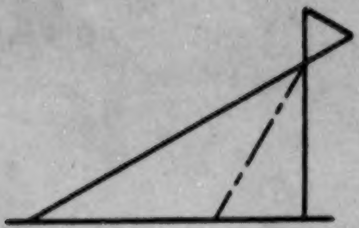
FRAME 98.

A pictomap, like a photomap, has bar scales for distance measurements, grid squares for location of objects, and a declination diagram for the plotting of azimuths. It also has a legend and other marginal data to explain the topographic symbols, just as do ____________________________ maps.

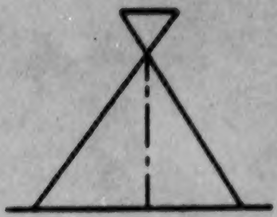
(horizon) (5)

FRAME 6.

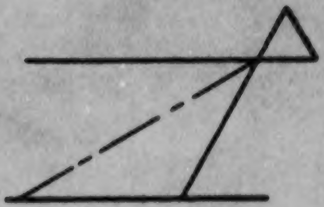
The sketch shows the camera pointed for high oblique, low oblique, and vertical aerial photographs. Which of the following camera positions will produce a vertical photograph?



A



B



C

(directions) (36)

FRAME 37.

With the photograph oriented to the ground, sighting the compass toward any object will result in which reading?

a. magnetic azimuth b. distance c. elevation

(shape, shadow, relation) (67)

FRAME 68.

As you have seen, tone (or texture) can also aid in identification. Refer to Photo A. The woods in grid square 5047 show a rough or mottled ________.

(topographic) (98)

FRAME 99. INFORMATION FRAME.

Pictomaps, like photomaps, sometimes contain distortions of the photo image owing to relief. When this is the case, the pictomap should be used only to supplement the information on a topographic map. A note in the margin informs the user of this condition. If the pictomap was prepared from an orthophotomap (see frame 88), the photo detail is as accurately positioned and scaled as on a topographic map and the note is omitted. Refer to the Fort Belvoir pictomap. Notice the caution note printed in red on the left side of the lower margin. Distances measured on this pictomap should be considered approximate; those along level stretches of ground are more reliable than those in the areas of relief variations. Azimuths are also subject to error because of the possible displacement of the photo image.

615

(b. distance) (6)

FRAME 7.

When aerial photography is made for reconnaissance or map-making purposes, the aerial camera takes a series of pictures, called a flight, as the aircraft flies along. Each succeeding photograph in a flight overlaps the one before by a planned amount, as shown in Panel 6-4. The series of overlapping aerial photographs taken as the aircraft flies along is called a ____________________.

(a. magnetic azimuth) (37)

FRAME 38.

To find the magnetic north direction on a photo when a map is not available, at least two objects (for example, a church and a crossroads) which appear on the photo must also be identified on the ground. The magnetic azimuth between these two points on the ground is determined with a compass. The line of direction between the images of these two points on the photograph represents the same magnetic azimuth, and can be used to plot the ____________________ north line on the photograph.

(tone (texture)) (68)

FRAME 69.

A slow flowing river (also undisturbed lakes or ponds) shows a smooth, even texture or tone. If the water surfaces were roughened (fast flowing river or wind blown pond), the photograph would show a rough ________.

Set 6-10. OVERLAYS

(Go on to next frame) (99)

FRAME 100. INFORMATION FRAME.

It is often necessary to indicate the position of units, fortifications, etc., as well as the natural and manmade features shown on a map or photograph. This enables you to "see" these units in their relation to the ground features shown on the map. To accomplish this, an overlay — a translucent (almost clear) or transparent (clear) sheet of paper or plastic — is positioned on the map and the military symbols of units, etc., are drawn on this overlay in their proper positions with reference to the map beneath.

630

617

Set 6-2. USE OF MARGINAL INFORMATION ON PHOTOS

(flight) (7)

FRAME 8. INFORMATION FRAME.

Photo intelligence analysts and map makers use special equipment to study overlapping pairs of photographs. Single photographs, however, are valuable sources of information if you know how to read them. The margins on the photograph contain much information about how, when, and where the photograph was taken. This information is used to locate the photograph with relation to the ground, to determine the scale of the photograph and to aid in the identification of images on the photograph.

(magnetic) (38)

FRAME 39.

To orient a photo in the field when a compass is not available, find at least two distinctive objects on the photo which you can identify on the ground. Rotate the photo until the photo images of the objects are in the same direction and relationship as on the ground. Your photo is now ____________________.

631

618

(texture (tone)) (69)

FRAME 70.

Refer to photograph A, furnished with this text. The identification factors will be used to identify the school in the upper left corner of grid square 5151.

1. The object is much larger than a house when compared with the ______________ of the houses in the nearby development.

2. The angular outline or ______________ identifies it as a manmade rather than a natural feature.

3. The ______________ of the object is different from surrounding areas, either natural fields or paved areas.

4. The ______________ cast by the object indicates that it is a sprawling structure, taller than individual houses, but lower than most office or apartment buildings.

5. Its ______________ to the athletic fields which make up most of the surrounding grounds makes its identification as a school most logical.

(Go on to next frame) (100)

FRAME 101.

By means of an overlay, both the symbols for units, fortified positions, etc. and the features on the map can be read at the same time. However, information can be of little value unless the user can refer it to the map for which it was prepared. Therefore, the preparer must identify the ______________ for which the overlay was prepared.

632

(Go on to next frame) (8)

FRAME 9.

Photographs in each flight are numbered in sequence and the number placed in the margin of the photograph. To identify a particular photograph in a flight, you must locate its exposure number in the ______________________ of the photograph.

Set 6-5. LOCATING POINTS BY POINT DESIGNATION GRID

(oriented) (39)

FRAME 40. INFORMATION FRAME.

To locate points on a photograph, a point designation grid is used, just as the military grid is used to locate points on a map. However, the method of point location is the only similarity between the uses of the two kinds of grids. On a large-scale map, the distance between grid lines represents a specific distance on the ground — 1,000 meters — and the vertical grid lines represent the direction of grid north. But on an aerial photograph, the point designation grid cannot represent a specific ground distance because the scale of each photo varies, whereas the spacing between grid lines remains constant. And since the construction of the point designation grid is based on the format of the photo, it does not represent any particular direction. The point designation grid is used solely to locate points on a photograph.

Set 6-7. PHOTO ORIENTATION FOR STUDY

(1. size, 2. shape, 3. tone, 4. shadow, 5. relation) (70)

FRAME 71. INFORMATION FRAME.

You have learned in previous frames how to orient a photo to a map or to the ground. For example, you learned how to locate magnetic north on the photo as an aid to such orientation. In the next few frames, you will learn how to position a photo with relationship to a source of light, to better study and identify the features on it. This is called "orientation for study."

(map) (101)

FRAME 102.

Overlays can be used as annexes to orders or reports to clarify or augment the written information. Military symbols (units, fortifications, etc.) would be found on the ______________ to further augment and clarify ______________ directives.

(margin) (9)

FRAME 10.

In addition to the photo exposure number, the sortie or mission number is also given in the margin of the photograph. These items identify a particular photograph. To identify a photo you need two numbers, ____________________ and ____________________.

(Go on to next frame) (40)

FRAME 41.

The point designation grid is added by the user to each photograph. Copies of the same photograph may be used by many different people. Therefore, each user must orient and draw the point designation grid in exactly the same way. Otherwise, the point location on one copy will not agree with the ____________ ____________ on the other copies.

622

(Go on to next frame) (71)

FRAME 72.

In orienting the photo for study, first turn so that you face a source of light, such as a window or a lamp. Next, turn the photo until the shadows of the objects on the photo point toward you (Panel 6-13). This creates a natural relation of light, images, and shadows. As long as you keep this relation, the photograph is

________________ for ________________.

(overlay, written) (102)

FRAME 103.

Register marks are traced from the map to aid you in accurately positioning the overlay on your map. Register marks may be grid line intersections, road crossings, fiducial marks (on photographs), or even the corners of a map or photograph. Refer to your overlay. The register marks, labeled 30-60 and 40-70, refer to which points on the LEAVENWORTH map?

a. grid line intersections b. fiducial marks c. map corners

636

623

(exposure, sortie or mission) (10)

FRAME 11.

A complete sequence of marginal information appears on the first and last exposure of each flight. Only selected items are given on the intermediate photographs. Where can you find the complete data if it is not on your photo?

a. The next photograph in the flight.
b. The first or last photograph in the flight.
c. The overlapping photograph in an adjoining flight.

(point location) (41)

FRAME 42.

The point designation grid is drawn by the ____________________ and all point designation grids are drawn in the ____________________ way. In the next few frames you will learn how to draw a point designation grid.

(oriented, study) (72)

FRAME 73.

With the photo oriented for study, an illusion of relief is created. The "shapes" (high and low places) are apparent although their amount is not measurable. Orientation for study thus creates the illusion of ____________________.

(a. grid line intersections. The 30-60 and 40-70 are grid line labels.) (103)

FRAME 104.

The user can place the overlay on the map in the same position as when it was made if he uses the register marks. On your LEAVENWORTH overlay (and on most military overlays) the register marks are ____________________.

(b. The first or last photograph in the flight) (11)

FRAME 12.

Panel 6-5 illustrates two methods of showing marginal information on aerial photographs. One system is manually lettered; the other records the data automatically as each picture is taken. The style of automatic recording depends upon the kind of camera used. Regardless of the method used, the same information is given. Study photograph A, furnished with this text. Is the marginal data manually lettered or automatically recorded?

(user, same) (42)

FRAME 43.

Panel 6-7 shows four steps in constructing a point designation grid.

Step 1. Locate the center of the four edges of the photograph. Most photographs have reference marks, called "fiducial marks," which mark the ________ of each edge.

(relief) (73)

FRAME 74.

Refer to the aerial photograph in Panel 6-14. If you look closely at the photo, you can see that the shadows point generally toward the right-hand margin of the photo. To orient the photo for study you must turn it so that the shadows (and right margin) are (toward) (away from) you.

(grid line intersections) (104)

FRAME 105.

A minimum of two ______________ ______________ are needed to replace the overlay in its correct position.

Note: All paper is subject to changes in size, shrinking or expanding because of heat and humidity. Different kinds of paper are affected in different ways. For this reason, the register marks on the furnished overlay may not fit exactly on the indicated grid intersections on the map. In such cases, position the overlay to the best average fit.

(manually lettered) (12)

FRAME 13.

Refer again to Panel 6-5 and to the furnished photograph, Photo A. What is the focal length of the camera used to take the photograph?

(center) (43)

FRAME 44.

Step 2. Connect opposite fiducial marks with straight lines. The horizontal and vertical lines will cross at the ________________ of the photograph.

(toward) (74)

FRAME 75.

Holding the photo (Panel 6-14) in this position, turn to face a source of light. You should be able to "see" some of the hills and valleys or the ______________ on the photo. You see that a gorge or ravine crosses the photo. If you position the photo the wrong way (with the shadows pointing away from you) the ravine looks like a winding ______________________. Study other objects (especially manmade ones) carefully to make sure that you have turned the shadows correctly toward you.

(register marks) (105)

FRAME 106.

Refer again to your LEAVENWORTH map overlay. Identification of the overlay is made in a title box drawn in an unused area of the overlay. The title box must contain the title of the map for which the ____________________ was prepared.

(6") (13)

FRAME 14.

To read the photograph properly, the photo user needs to know the flight altitude — how high the aircraft was flying when the picture was taken. In the automatically recorded marginal data, a picture of an altimeter is usually recorded on the side of the photograph. On the furnished photo, the altitude is lettered in the margin. How high above sea level was the aircraft flying when this photo was taken?

(center) (44)

FRAME 45.

Step 3. The rest of the grid lines are spaced exactly 4 centimeters (1.575 inches) apart, starting from the center lines in each direction. Each square in all point designation grids measures ______________ cm on each side.

(relief, ridge) (75)

(Note: This technique is a form of optical illusion and depends on time of day of photography, relief involved, and even the photo processing. If you don't suddenly "see" relief, it may be due to the above causes or it may take awhile to train your eyes to see it.)

FRAME 76.

There are no contour lines or elevations on an aerial photograph. Even the orientation for study gives only a "picture" view of relief. Therefore, which measurement cannot be made on an aerial photograph?

a. distance b. direction c. elevation

(overlay) (106)

FRAME 107.

The title identifies the map and the objective describes what the overlay is trying to show. Refer to the overlay; the objective of the overlay is ____________________________________.

Set 6-3. SCALE OF PHOTOGRAPHS (MEASURING GROUND DISTANCES)

(7000 feet above sea level) (14)

FRAME 15.

Distance measurements on a vertical aerial photograph depend upon the scale (RF) of the photograph just as do distances on a map.

$$\text{Photo RF} = \frac{\text{photo distance}}{\text{ground distance}} = \frac{PD}{GD} \quad \text{(Panel 6-6)}$$

The RF of the photograph is the ratio (or fraction) of ____________ distance to ground distance.

---

(4) (45)

FRAME 46.

Step 4. To number grid lines, you must first turn the photo until the exposure number and any manually lettered marginal information is in the normal reading position. On most photographs, this would place the exposure number in the upper left corner. Any time you use a point designation grid, you must place the marginal information in the ____________ ____________ position.

Set 6-8. PHOTOMAPS

(c. elevation) (76)

FRAME 77.

Two or more adjoining and overlapping aerial photographs can be "joined" by matching the same images in the overlap area. The resulting larger "photograph" is called a mosaic. The ________________ can be extended to cover a large area by adding more overlapping (and sidelapping) photos. (Panel 6-15)

(situation report) (107

FRAME 108.

Since military situations can change rapidly, the time and date of the information are also included in the ________________ ________________.

(photo) (15)

FRAME 16. INFORMATION FRAME.

Ground distance on the photo may be determined in one of three ways: by actually measuring the distance on the ground between two points that appear on the photo; by identifying and measuring on the photo the image of some feature or object whose actual dimensions are known; or by relating the measurement between two points on a photograph to the measurement between the same two points on a map of known scale.

(normal reading) (46)

FRAME 47.

Refer to Panel 6-7. The center lines, both vertical and horizontal, are numbered 50. The numbers of the vertical lines increase (read) to the __________. Numbers along the horizontal lines increase up. The numbers desgnating the ____________________ lines of the photo will always be as shown in the margin.

(mosaic) (77)

FRAME 78.

Adding a standard military grid, marginal information, and names to a mosaic, and printing it at a definite map scale produces a photomap (Panel 6-16). A ________________ contains many features similar to a topographic map and is quicker to produce.

(title box) (108)

FRAME 109.

To prove that the overlay is authentic, the name, rank and organization of the author must be included. The author's signature fixes ________________ for the data on the overlay.

(Go on to next frame) (16)

FRAME 17.

In computing photo RF, both ground distance and photo distance must be expressed in the same unit. If inches are used in the numerator (photo distance), inches must also be used in the denominator (ground distance). If the distance between two points on a photograph is measured as one inch, and on the ground the same distance is measured as one mile (63,360 inches), what is the RF of the photo?

a. $\frac{1}{12}$ b. $\frac{1}{5,280}$ c. $\frac{1}{63,360}$

(right, grid) (47)

FRAME 48.

Again look at step 4 of Panel 6-7. The grid lines are numbered to read right and up (just as on a map). Grid square 5252 will always be located in which quarter of the photo?

a. upper left b. upper right c. lower right (photomap) (78)

FRAME 79.

A photomap is a mosaic (many overlapping photographs) which is printed in a map size and shape. The features on a ________________ are not symbols, but photographic images.

(responsibility) (109)

FRAME 110.

The title box on the overlay furnished with this text identifies the following:

1. ________________ (title)
2. ________________ (objective)
3. ________________ (data of overlay)
4. ________________ (rank of author)

650

(c. $\frac{1}{63,360}$) (17)

FRAME 18.

When the scale of the photo is large, it is often possible to identify and measure features that have standard known dimensions, such as athletic fields, large aircraft with known wing spans, or naval vessels of known length. For example, the 10-yard lines on a football field are usually clearly marked, and can be identified on a large-scale photograph. The length of the field is standard — 300 feet, or 360 feet if the end zones are included. The RF is computed by converting the known length of the football field (GD) to the same unit of measurement used on the photo (PD). Features of known dimension can be used in the formula $\frac{PD}{GD} = RF$ because their ________________ distance is known.

(b. upper right) (48)

FRAME 49.

Points are located on the point designation grid using 6-digit coordinates (as on a map). A _____-digit reading to the right is combined with a _____-digit reading up.

638

(photomap) (79)

FRAME 80.

Refer again to the photomap on the reverse side of the LEAVENWORTH map. Which of the following information on a topographic map is not shown on the photomap?

a. grids   b. declination diagram   c. legend

---

1. Leavenworth 1:50,000 map (sheet 7062 IV)
2. SIT REP
3. 9 Sept 65
4. 2d Lieutenant (110)

FRAME 111.

Information drawn on the overlay need not duplicate the topographic symbols unless the overlay shows a change in a topographic feature on the map. The symbols on the enclosed overlay are ________________ symbols and do not duplicate the map information.

652

639

(ground) (18)

FRAME 19.

If you identify a football field on a photograph, and measure its length (without the end zones) as .36 inch, what is the scale of the photo?

a. $\frac{1}{3600}$ b. $\frac{1}{7200}$ c. $\frac{1}{10,000}$

(3, 3) (49)

FRAME 50.

The first 2 digits (both right and up) are the two figures with which the lines are numbered and represent the lower left-hand corner of the grid square. The third digit (in each instance) is the distance measured within the grid square. Thus, a point located in the exact center of grid square 4949 has 6-digit coordinates of ________________.

653

(c. legend. Images on the photomap are photographic and a symbol legend is not needed) (80)

FRAME 81.

The photomap is an excellent map substitute within its limits. It has a scale for distance measurements, and grid lines for location and direction measurements. Which measurement cannot be made on a photomap?

a. distance b. direction c. relief

(military) (111)

FRAME 112.

Other useful information, such as scale and north arrow on a photograph, are added where necessary. North arrows are not needed on map overlays because the vertical grid lines identify grid ________________.

(c. $\frac{1}{10,000}$. 300 ft. × 12 = 3600 in.

$\frac{PD}{GD} = \frac{.36}{3600} = \frac{1}{10,000}$) (19)

FRAME 20.

When a map of the same area is available, the ground distance (GD) between two points can be obtained by multiplying the measured map distance (MD) by the denominator of the map RF. For example, 1 inch on a map having an RF of $\frac{1}{50,000}$ equals 50,000 inches of ground distance. This can then be used with the measured photo distance between the same two points in the formula $\frac{PD}{GD}$ = RF of photo.

You can use a map of the same area to determine the scale of a photo because you can determine the ________________ ________________ from the map.

(495495) (50)

FRAME 51. INFORMATION FRAME.

Because the same point designation grid numbers are used on all photomaps, the coordinates of a point on the photograph must be preceded by the mission and exposure numbers to identify the photograph when reporting a photo point location. The grid reference consists of three parts:

1. The letters "PDG" to indicate aerial photo coordinates rather than map grid coordinates.
2. The mission and exposure numbers of the photograph.
3. The six digits which actually locate the point on a photograph.

(c. relief) (81)

FRAME 82.

Refer to the LEAVENWORTH photomap. The grid on it is a standard military grid. As you learned concerning the grid on the LEAVENWORTH topographic map, the length of each side of the grid square is _________ meters.

(north) (112)

FRAME 113.

Detailed route information is given on the route reconnaissance overlay illustrated in Panel 6-17. Special route reconnaissance symbols (identified in FM 5-36) indicate critical widths and clearances, curves, and gradients. The road slope north of the river is shown by methods described in Part V, frame 43. What is the slope?

a. 1/10

b. 8 percent

c. 6 degrees

(ground distance) (20)

FRAME 21.

When you have a map of the same area, you can combine the steps of finding the ground distance, and then the photo scale, by using the formula

$$\frac{PD}{MD} \times \text{Map RF} = \text{Photo RF}$$

Example: The photo distance between two points is 10 centimeters. On a 1:50,000 scale map, the map distance between the same two points is 5 centimeters. Substituting in the formula: Photo RF $= \frac{10}{5} \times \frac{1}{50,000}$, what is the RF of the photo?

a. $\frac{1}{25,000}$ b. $\frac{1}{50,000}$ c. $\frac{1}{100,000}$

(Go on to next frame.) (51)

FRAME 52.

Refer to photograph A supplied with this text. The exposure number is 565. What is the mission number?

a. M-109 b. 0730 Z c. VV702

644

(1000) (82)

FRAME 83.

A standard military grid on the photomap permits reading 6-digit grid coordinates. Locate RJ 997 (road junction, elevation 997) in grid square 4664. What are the 6-digit coordinates for this point?

a. 460640 b. 462644 c. 468646

(b. 8 percent) (113)

FRAME 114.

The ________________ ________________ in the lower right corner must be filled out with pertinent information to identify the overlay.

659

645

$(\frac{1}{25,000})$ (21)

FRAME 22.

The photo RF ratio, $\frac{\text{photo distance}}{\text{ground distance}}$, is in the same proportion as $\frac{\text{focal length of lens}}{\text{height of camera}}$ (see Panel 6-6) $\frac{\text{photo distance}}{\text{ground distance}} = \frac{\text{focal length of lens}}{\text{height of camera}}$

What is the focal length given on the photo furnished with this text?

a. 702 b. 6 in. c. 7000′

(a. M-109) (52)

FRAME 53.

The sides of the 4-cm grid squares of the point designation grid (PDG) are exactly the same size as the RF 1:25,000 map scale shown on your protractor. This scale can be used to find the 3d and 6th digits of PDG coordinates. Using this scale, which of the following locates a baseball diamond on Photo A?

a. PDG M-109 565 508509

b. PDG M-109 565 494483

c. PDG M-109 565 486507

659

646

(c. 468646) (83)

FRAME 84.

The road leading south from RF 997 is pointed directly at Platte City. The grid azimuth of the road is 181½ degrees. What magnetic azimuth (see frame 4-84, Part 4) would describe this direction to Platte City?

a. 172   b. 181½   c. 191

(title box) (114)

FRAME 115.

The register marks on the route reconnaissance overlay indicate that it is referred to a map, because the register marks are ____________________ ____________________ intersections.

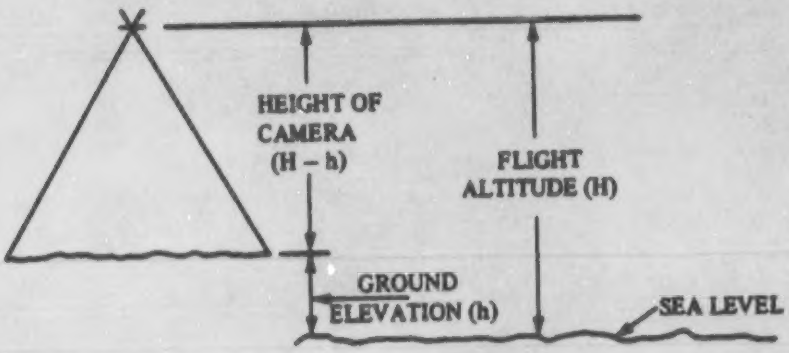
660

647

(6 in.) (22)

FRAME 23.

The flight altitude, given on the photograph, is measured from mean sea level (see sketch). The average ground elevation above mean sea level must also be determined and subtracted from the flight altitude to find the height of the camera above the ground. To determine "height of camera" you must subtract ________________ ________________ from the flight altitude.



(a. PDG M-109 565 508509) (53)

FRAME 54.

To review, the lines on a point designation grid cannot be used to find either distance or direction on the ground. They can be used ONLY for which of the following?

a. determining direction b. locating points c. measuring distances

661

(a. 172. You must subtract the GM angle (grid to magnetic)). (See instructions in declination diagram on Leavenworth photomap.) (84)

FRAME 85.

Refer to grid square 4764, just east of RJ 997. The topographic map shows mostly relief information and some woods in this square. On the photomap, you see fence lines, woods outlines, and even individual trees. For example, on the topographic map, 476646 refers to a point on the contour marking the hilltop. What is the description of this same location on the photomap?

a. woods patch b. fence corner c. road junction

Set 6-11. MILITARY SKETCH MAPS

(grid line) (115)

FRAME 116.

A military sketch is a drawing on a sheet of opaque (not transparent) paper. It usually substitutes for, rather than supplements, a map. A ________________ is drawn to satisfy a tactical or administrative requirement.

(ground elevation) (23)

FRAME 24.

The RF ratio can now be expressed as:

Photo RF $= \frac{fl}{H\text{-}h}$, where fl = focal length
H = flight altitude
h = ground elevation

Which of these three values is not given in the marginal information?

a. fl b. H c. h

Set 6-6. IDENTIFYING OBJECTS ON PHOTO

(b. locating points) (54)

FRAME 55.

The legend on the LEAVENWORTH map helped you identify (recognize) streams, roads, hills and other features. You have to identify objects on a photograph without help from a ____________.

(b. fence corner) (85)

FRAME 86.

A photomap furnishes a great amount of detail which is not shown on the topographic map. This is due to the photomap's ______________ images.

(sketch) (116)

FRAME 117.

Sketches vary from freehand drawings to carefully diagrammed ones. Since a sketch may not be referred to a map, its identification (title, objective, date and author) in its ____________ ____________ must be complete.

(c. h. The ground elevation is not given on the photo. Altitude and focal length of camera are.) (24)

FRAME 25.

$$\text{Photo RF} = \frac{\text{fl}}{\text{H-h}}$$

To obtain average ground elevation (h), you can use a topographic map of the same area as your photo. If a map is not available, you obtain the average ground elevation from reconnaissance reports and other intelligence sources. If you have a map, plot the area covered by your photo on the map, and determine the high and low elevations from the contours. To obtain average ground elevation from a map, you must check the __________________ in the area covered by the photo.

(legend) (55)

FRAME 56.

The colors on a topographic map help you identify streams and swamps, orchards and woods, and built-up areas. You have to identify objects on aerial photographs without the assistance of __________________.

652

(photographic) (86)

FRAME 87.

Photomaps are usually used as map supplements. Because photomaps are made from aerial photographs, they sometimes contain distortions. If the photos are slightly tilted, or the terrain very rugged, the photo images of features are displaced, and measurements of distance and direction are not reliable. Such photomaps are usually used with topographic maps to provide new or additional information. They are used as map ______________.

(title box) (117)

FRAME 118.

Panel 6-18 illustrates a strip map, a type of sketch, to be used by a vehicle convoy. The information shows routes to follow, general directions, distances, and checkpoints. Refer to the strip map. What types of topographic symbols are added as check points?

a. road surface classification

b. stream, road and railroad crossings

c. elevations

666

(contours) (25)

FRAME 26.

Refer to photograph A furnished with this text. By studying the contours and spot elevations on a large-scale map of Northern Virginia, you determine that the average ground elevation in the area covered by the photograph is 250 feet. Using this information and the flight altitude given in the margin of the photograph, what do you determine the scale of the photograph to be?

a. $\frac{1}{6750}$ b. $\frac{1}{13{,}500}$ c. $\frac{1}{14{,}000}$

(color) (56)

FRAME 57.

There are five factors which help you identify objects on an aerial photo:

1. size
2. shape or pattern
3. shadow
4. tone or texture
5. relation to other nearby features

In reading photographs, we use the recognition factors size, shape or pattern, ________________, tone or texture, and ________________ ________________ ________________ ________________.

654

(supplements) (87)

FRAME 88.

An orthophotomap is a special type of photomap which may be used in place of a topographic map. The photographs are printed with equipment that eliminates the scale and image distortions resulting from tilted photographs and from rugged relief. These are called **orthophotographs.** An orthophotomap, made from orthophotographs, is just as accurate as a topographic map. It may be used as a map ____________________.

(stream, road and railroad crossings) (118)

FRAME 119.

Another type of sketch (Panel 6-19) is more detailed than the strip map. The author has added his field notes and computations to the sketch. He started at an elevation of 34 meters. What is his finishing elevation?

a. 20.9 b. 72.2 c. 121.5

668

(b. $\frac{1}{13{,}500}$. $RF = \frac{f}{H\text{-}h} = \frac{6''}{7000' - 250'} = \frac{.5'}{6750} = \frac{1}{13{,}500}$) (26)

FRAME 27.

The photo scale for the areas of higher elevations is different from the scale for the lower areas of the same photograph. Therefore, photo scale is usually considered approximate unless the terrain is very level, or if special printing methods have been used. Differences in elevation may cause differences in ________________ within a single photograph.

(shadow, relation to other features) (57)

FRAME 58.

Size is a factor in identifying objects. In looking at the aerial photo of a portion of Fort Belvoir (Panel 6-8) you see buildings of various sizes. The large buildings include those containing offices, classroom buildings of the Engineer School, and barracks. You would assume that the small buildings on the semi-circular road at the top left of the photo might be family ________________.

Set 6-9. PICTOMAPS

(substitute) (88)

FRAME 89.

Pictomaps are a type of map product that is also made from photomosaics. However, the gray tones of the photo image are printed in natural colors on the pictomap. Some topographic map information is also overprinted in color on the photo image. The special map, FORT BELVOIR AND VICINITY, furnished with this text, is a pictomap.* A pictomap combines the features of a photomap printed in ________ ________ with many of the symbols of a ________ ________.

---

*See Note in materials list in front of this text.

(b. 72.2) (119)

FRAME 120.

The distances on the sketch were measured in strides, but the bar scale at the bottom of the sketch indicates that the distances were plotted in ________.

(scale) (27)

FRAME 28.

When the difference between the high and low elevations in a single photograph is very great, it is better to compute two separate scales than to use an average elevation. On most photographs, however, it is sufficient to use the ________________ ________________ to compute scale.

(quarters or housing) (58)

FRAME 59.

The shape of objects is used to identify them. Natural objects are usually irregular in shape. Look at Panel 6-9. You see that the manmade objects are ________________ in shape and contain ________________ lines.

658

(natural colors, topographic map) (89)

FRAME 90.

The pictomap's basic tone (tan color or "landtone") shows bare ground. Vegetation is shown in green ("vegetone"). The darker shades and shadows are emphasized by a black-green color ("shadowtone"). You would identify bare ground by ______________ color and vegetation by ______________ color.

(meters) (120)

FRAME 121.

Sketches may be drawn to cover areas as well as single routes. They may be combined with other area sketches to increase the ________________ that is covered.

(average elevation) (28)

FRAME 29.

If you know the scale of the photo, you can determine ground distance the same way as when using a map. Multiply the photo measurement by the denominator of the photo RF and convert to the desired unit of measurement, if necessary. What is the ground distance in feet between two points which are 2.4 inches apart on a photo whose RF is $\frac{1}{20,000}$?

a. 2400 b. 4000 c. 48,000

(regular, straight) (59)

FRAME 60.

Shadows of objects on aerial photos are used to identify them and also to determine their relative heights. Panel 6-10 is an aerial view of a prison. Notice that the water tower is easily identified by its shadow. The shadow of the water tower (upper left in photo) is ____________________ than the shadow of the guard tower in the corner of the prison wall (below and to the left of the water tower). You know from this that the water tower is ____________________ than the guard tower.

(tan, green) (90)

FRAME 91.

The darker shades and shadows are emphasized in ________________.

(area) (121)

FRAME 122.

Outpost sketches are made of the terrain ahead of an outpost line. The sketcher must rely on his sketching ability. If the sketcher makes his sketch from an OP, he is making a place sketch which is a form of ________________ sketch.

Set 6-4. FINDING DIRECTION ON A PHOTO

(b. 4000) (29)

FRAME 30. INFORMATION FRAME.

Directions on an aerial photograph are not shown as on a map. There are no military grid lines, nor are parallels and meridians shown. If a north direction is needed, it must be determined and plotted by the user. The exposure number and any manually lettered marginal data are usually shown along the leading edge of each photo — that is, the front edge as the aircraft was traveling. This edge is frequently referred to as the "top" of the photo, although it can be any compass direction, depending on the direction of flight.

(longer, higher (taller)) (60)

FRAME 61.

Tone and texture of objects shown in an aerial photo (Panel 6-11) provide clues to their identification. Woods and forests, for example, show a rough texture. Quiet ponds and lakes show a smooth tone or texture. The smooth tone or texture of the triangular shaped object below and to the right of the top center of the photo indicate it is a ________________ or ________________. The rough texture shown in most of the center and lower right areas of the photo indicate ________________ or ________________. (This photo was taken after a light snowfall.)

(black-green) (91)

FRAME 92.

Topographic information is overprinted on the pictomap. Contours and such cultural information as boundaries, railroads, and names are printed in black. Drainage features (swamps, rivers, etc.) are overprinted in blue and important roads and buildings in red. On a topographic map, as you have learned previously, the contours are printed in brown. In a pictomap, you would find contours printed in ____________________.

(outpost) (122)

FRAME 123.

Information on sketches is useless unless the user can identify the location of the sketch. The location is noted in the ________________ ________________.

663

(Go on to next frame) (30)

FRAME 31.

If a map is available, the photograph is oriented to the map, i.e., turned until the photo images of the ground features (roads, etc.) are in the same relation (directions as you look at them) as their equivalent map features. North on the photo will then coincide with (or be parallel to) north on the map. To find north, you ________________ the photo to the map.

Turn back to bottom of page 6-1 for frame 32

(pond or lake, woods or forests) (61)

FRAME 62.

The relation of an object to other nearby features on the photo can also help you to identify the object. In Panel 6-12, the building with the checkered roof close to the airplane parking apron of the airfield would be a ________________.

Turn back to top of page 6-2 for frame 63

677

664

(black) (92)

FRAME 93.

Refer to the special map, FORT BELVOIR AND VICINITY, furnished with this text. This is a pictomap. Notice that there is both photographic detail and topographic information. For example, in the housing development in grid square 1490, the exact street pattern and the individual homes are distinctly shown. This is a ________________ image of the housing development.

Turn back to bottom of page 6-2 for frame 94

(title box) (123)

END OF FRAMES FOR PART VI

678

6665

PANEL 6-1

PANEL 6-2

A Sample High Oblique Photograph

665A

PANEL 6-3

A Sample Low Oblique Photograph

665B

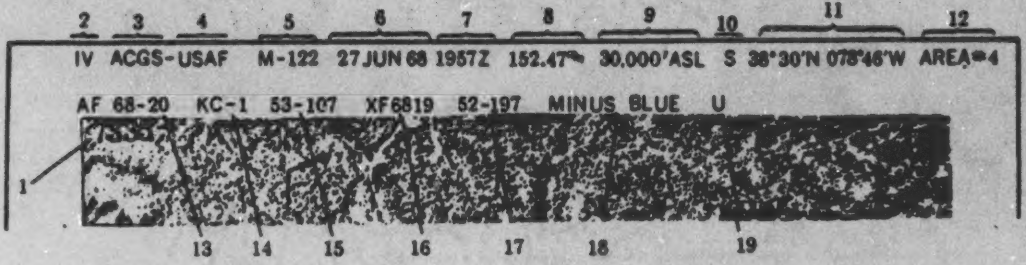
665c

PANEL 6-4

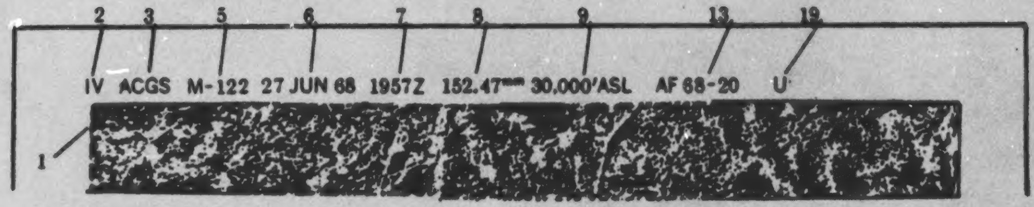
Sample Layout of Overlapping Flights

PANEL 6-5 — MARGINAL INFORMATION

a. DATA RECORDED MANUALLY


2
3
4
5
6
7
8
9
10
11
12
IV ACGS-USAF M-122 27 JUN 68 1957Z 152.47mm 30,000'ASL S 38°30'N 078°46'W AREA #4
AF 68-20 KC-1 53-107 XF6819 52-197 MINUS BLUE U
1
13
14
15
16
17
18
19

FOR FIRST AND LAST EXPOSURE OF EACH FLIGHT
INCLUDING LAST EXPOSURE OF EACH ROLL


2
3
5
6
7
8
9
13
19
IV ACGS M-122 27 JUN 68 1957Z 152.47mm 30,000'ASL AF 68-20 U
1

FOR INTERMEDIATE EXPOSURES

PANEL 6-5 — MARGINAL INFORMATION (Continued)

b. DATA RECORDED AUTOMATICALLY

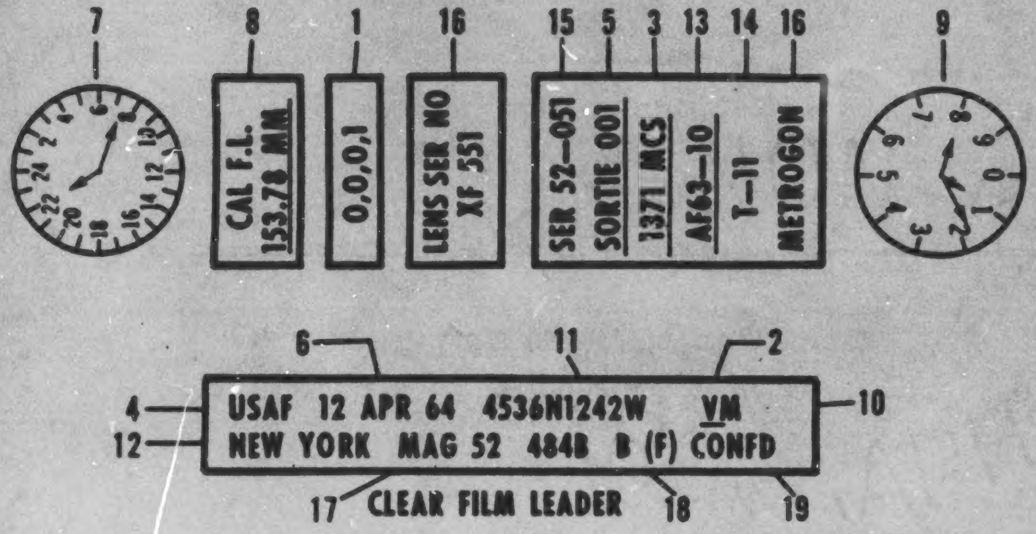

7
8
1
16
15
5
3
13
14
16
9
CAL F.L.
153.78 MM
0,0,0,1
LENS SER NO
XF 351
SER 52—051
SORTIE 001
1371 MCS
AF63—10
T—11
METROGON
6
11
2
4
10
12
USAF 12 APR 64 4536N1242W VM
NEW YORK MAG 52 484B B (F) CONFD
17
CLEAR FILM LEADER
18
19

PHOTO IDENTIFICATION DATA

1. EXPOSURE NUMBER
2. CAMERA POSITION
3. TAKING UNIT
4. SERVICE
5. SORTIE/MISSION NUMBER
6. DATE
7. TIME GROUP AND ZONE LETTER
8. FOCAL LENGTH
9. ALTITUDE
10. KIND OF PHOTOGRAPHY
11. GEOGRAPHIC COORDINATES
12. DESCRIPTIVE TITLE
13. PROJECT NUMBER OR CODE NAME
14. CAMERA TYPE AND SERIAL NUMBER
15. LENS CONE SERIAL NUMBER
16. LENS TYPE AND SERIAL NUMBER
17. MAGAZINE TYPE AND SERIAL NUMBER
18. FILM AND FILTER USED
19. SECURITY CLASSIFICATION

PANEL 6-6 — PHOTO RF

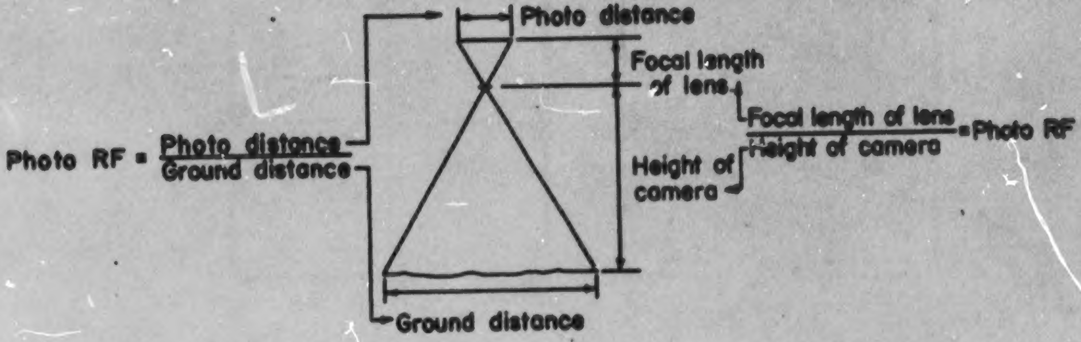
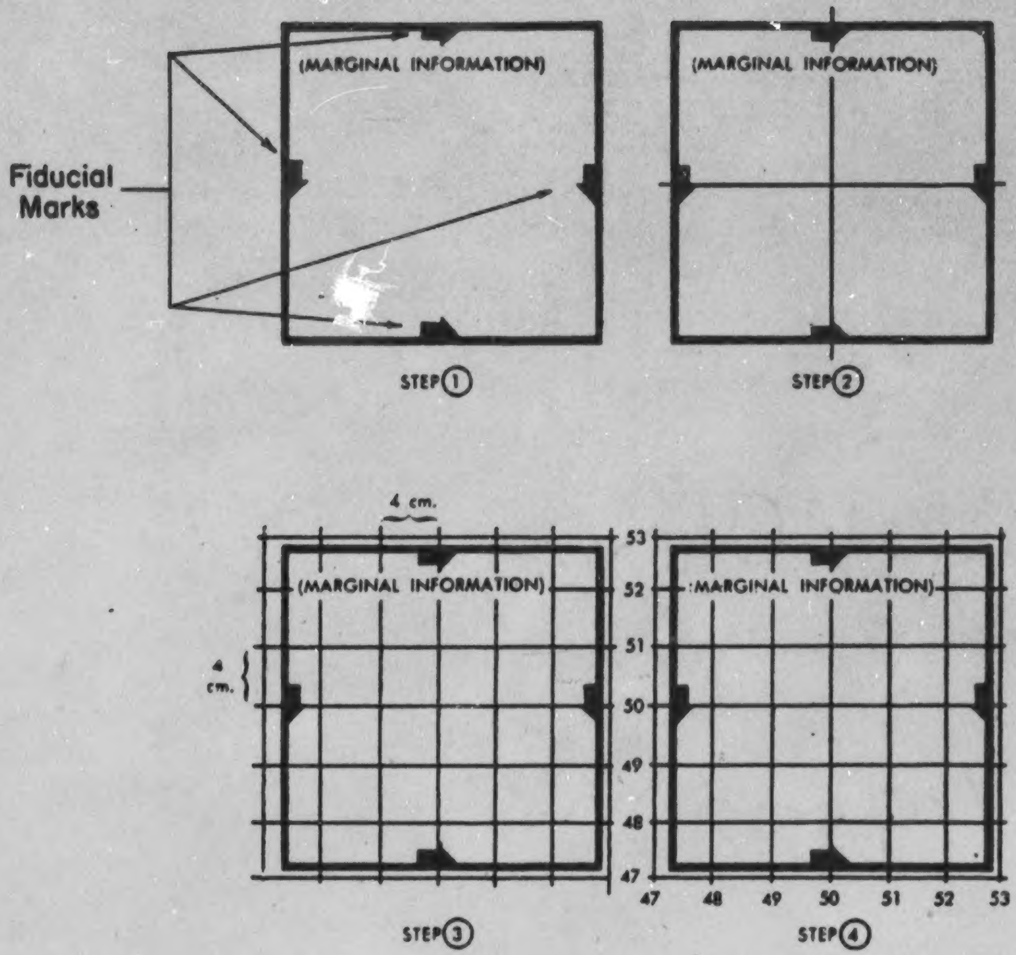


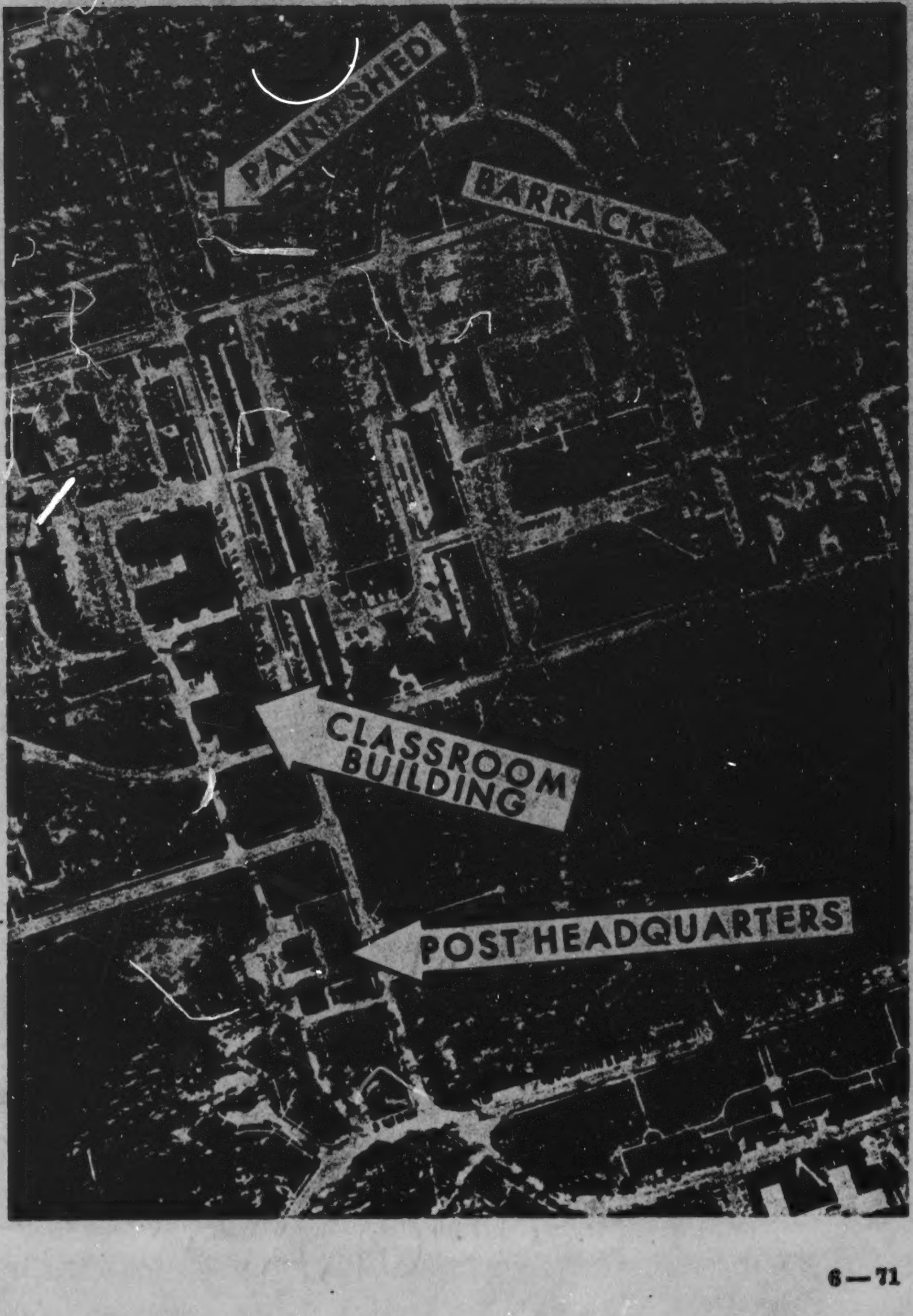
Photo RF = Photo distance / Ground distance
Photo distance
Focal length of lens
Focal length of lens / Height of camera = Photo RF
Height of camera
Ground distance

PANEL 6-7


Fiducial Marks
(MARGINAL INFORMATION)
(MARGINAL INFORMATION)
STEP①
STEP②
4 cm.
4 cm.
(MARGINAL INFORMATION)
:MARGINAL INFORMATION)
53
52
51
50
49
48
47
47
48
49
50
51
52
53
STEP③
STEP④

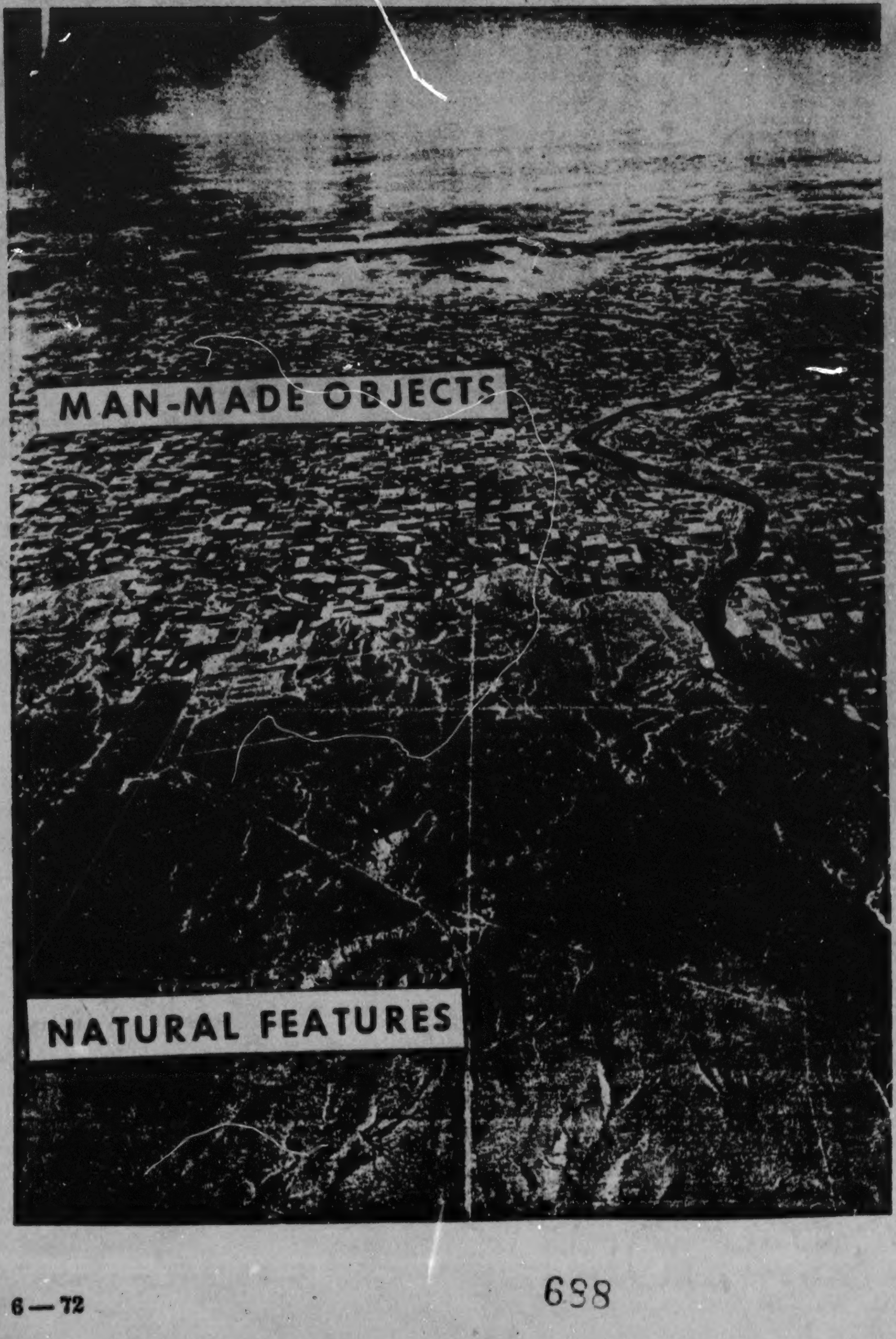
670

PANEL 6-8 — SIZE


PAINT SHED
BARRACK
CLASSROOM BUILDING
POST HEADQUARTERS

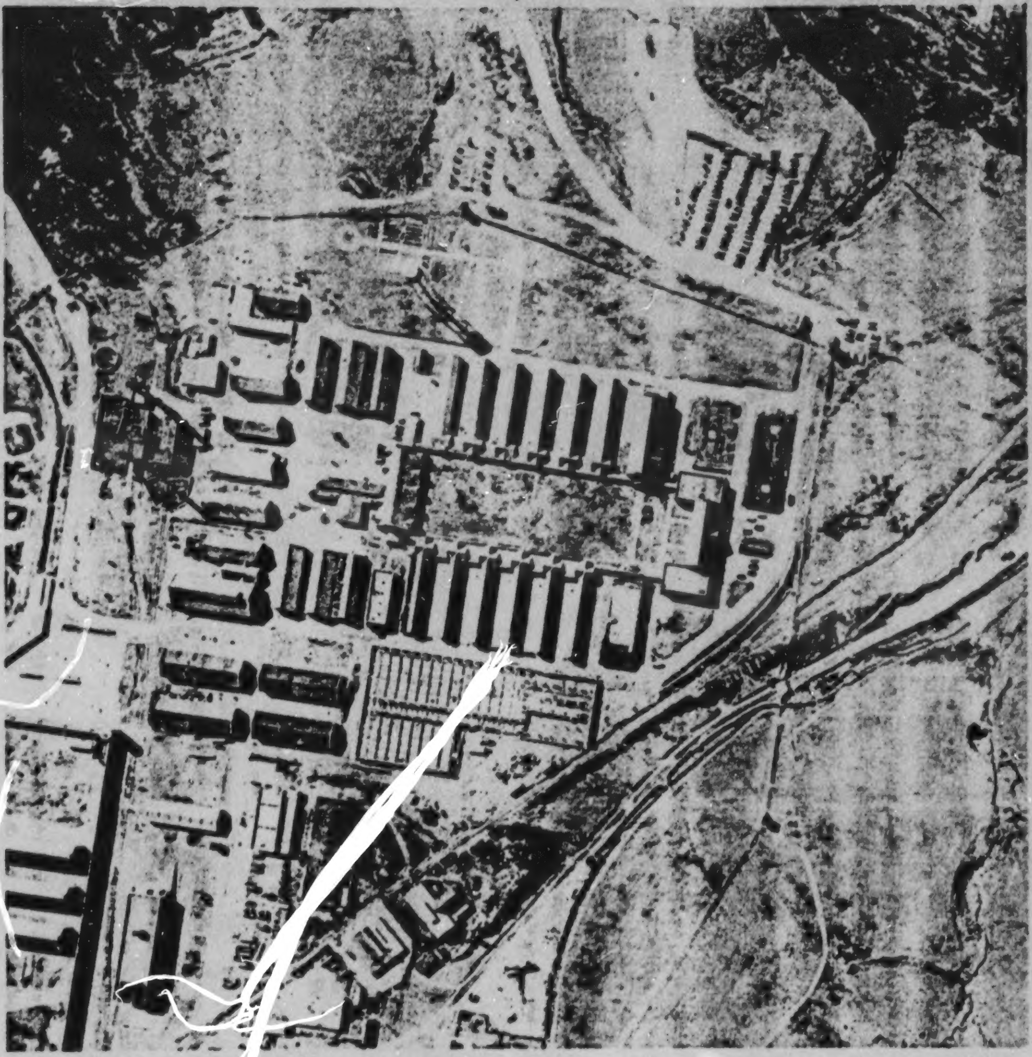
670A

PANEL 6-9 — SHAPE

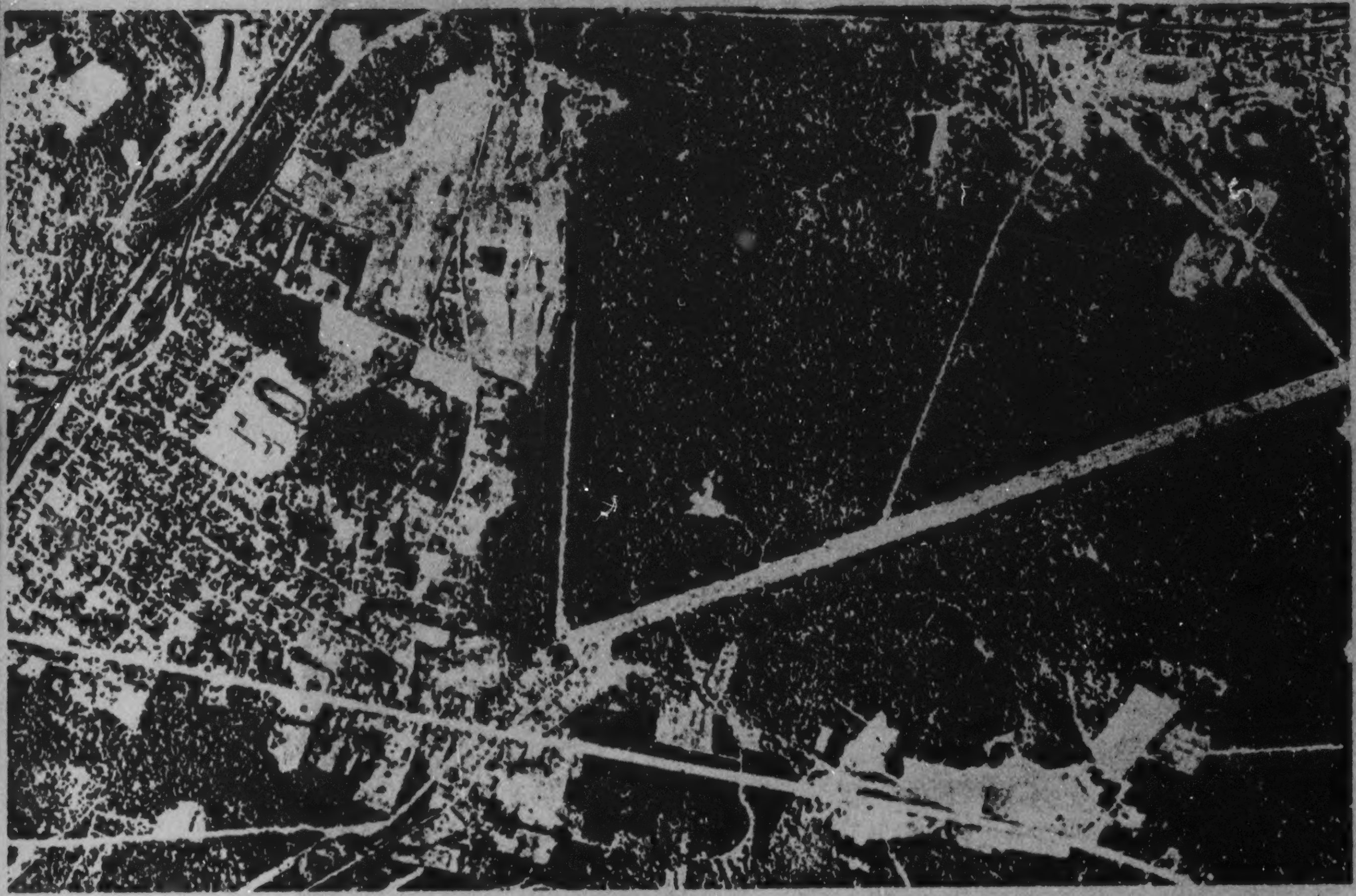

MAN-MADE OBJECTS
NATURAL FEATURES

6̲9̲0̲ B

PANEL 6-10 — SHADOW



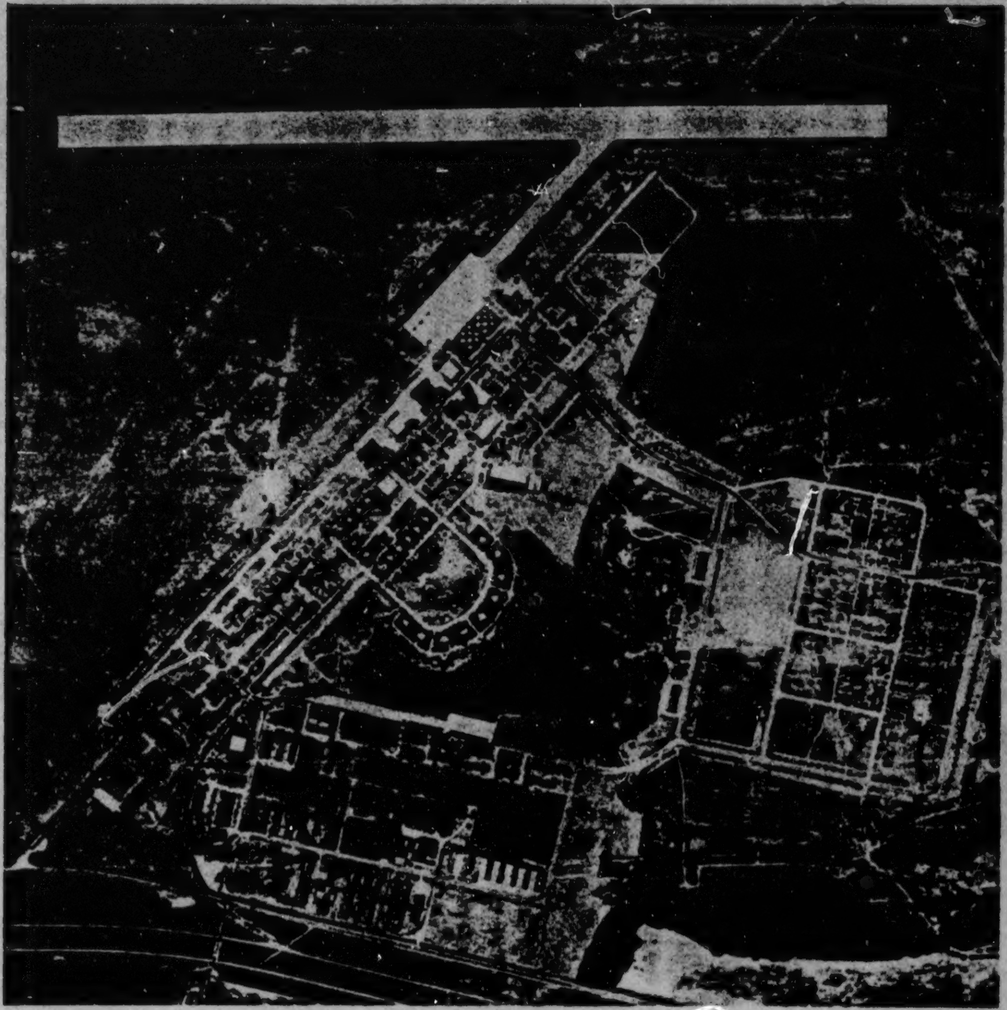
PANEL 6-11 TONE AND TEXTURE



670c

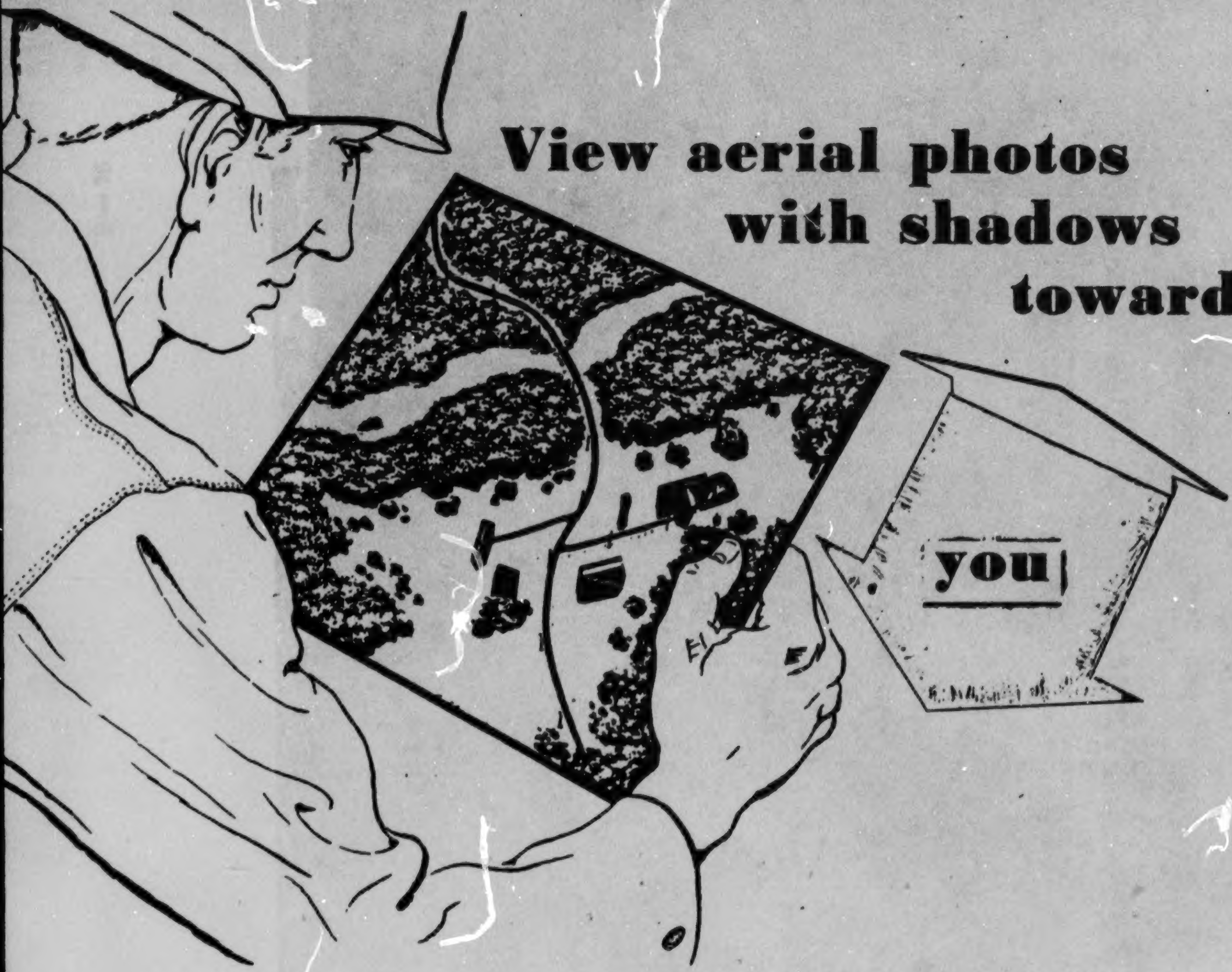
670D

PANEL 6-12 RELATION TO OTHER FEATURES



691

View aerial photos with shadows toward you

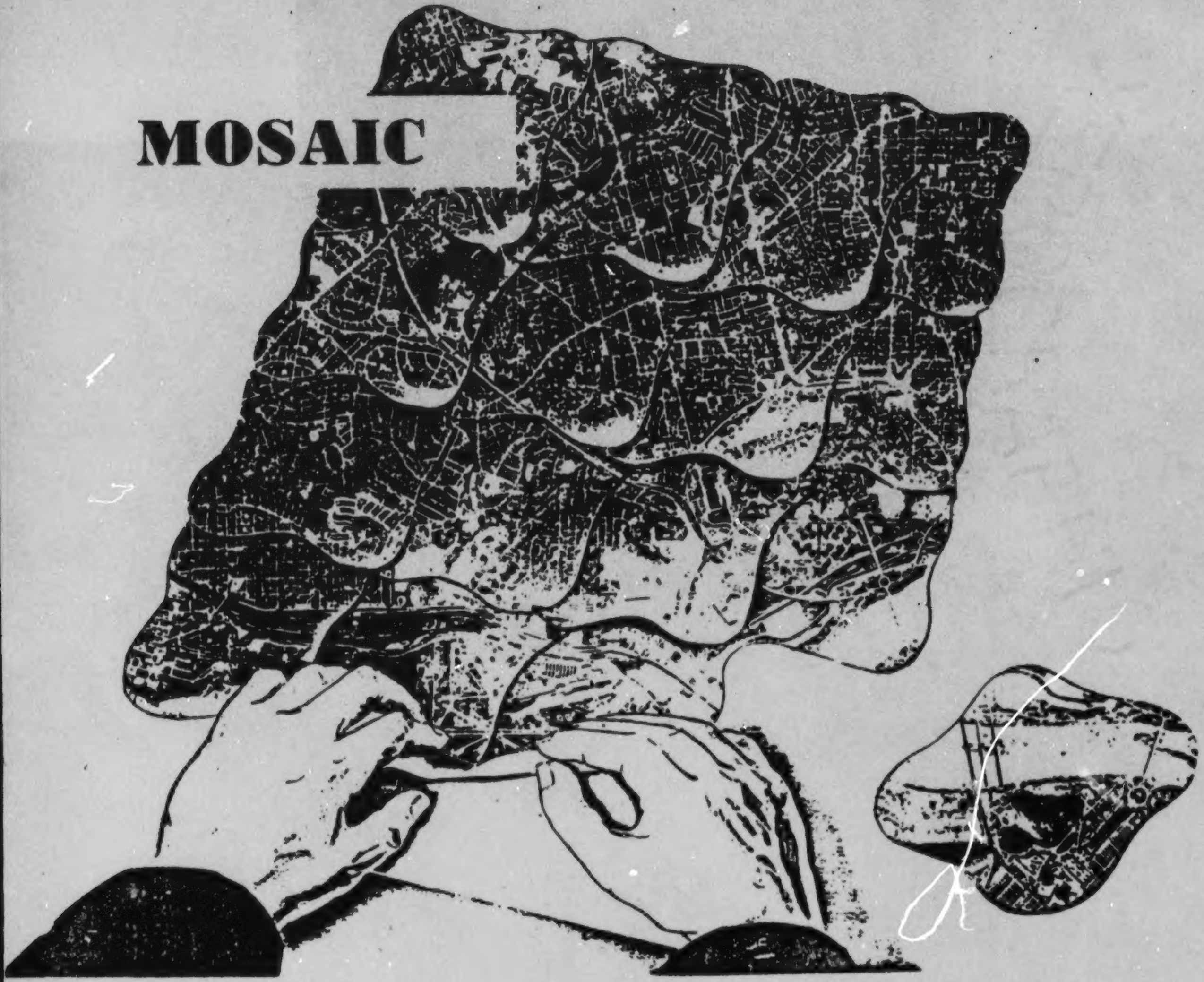


PANEL 6-13

671A

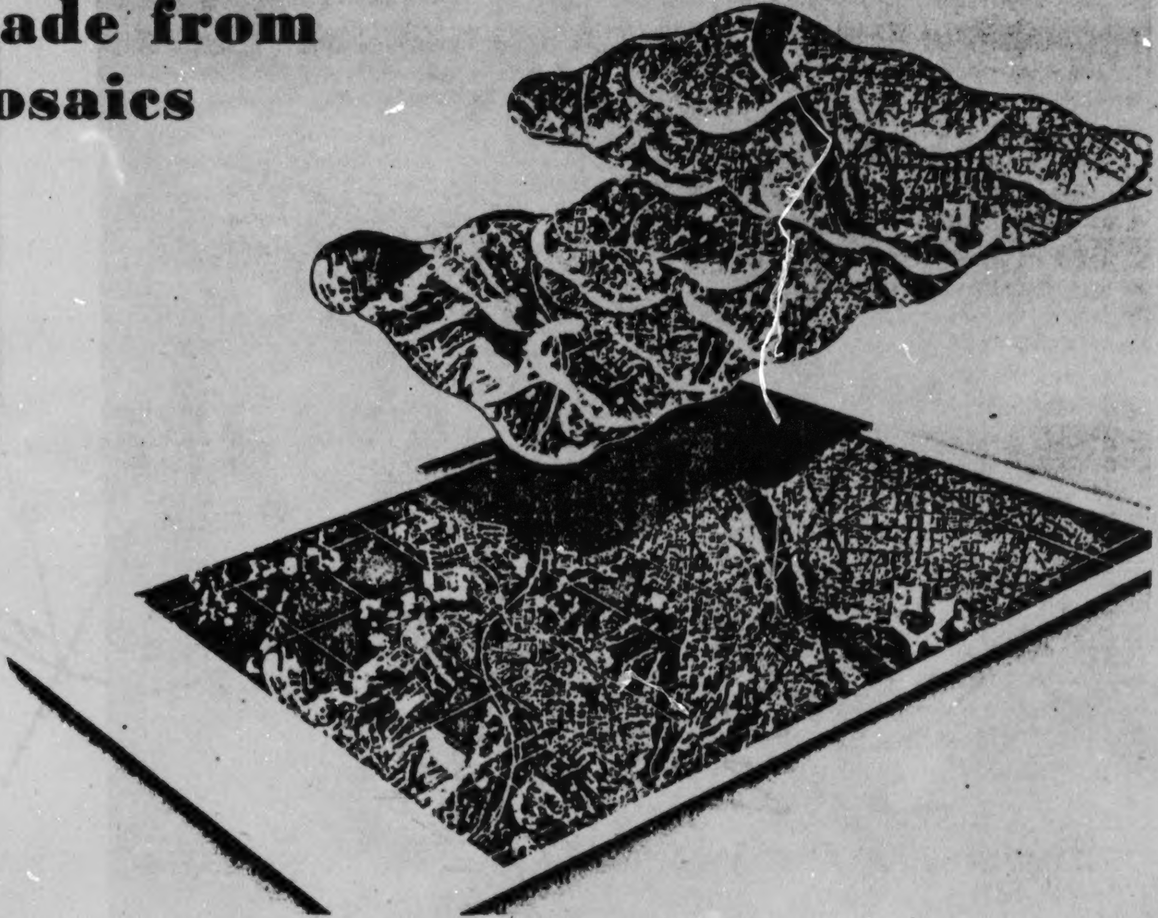
PANEL 6-14 — AERIAL PHOTO

MOSAIC



PANEL 6-15

PHOTO MAPS are made from mosaics



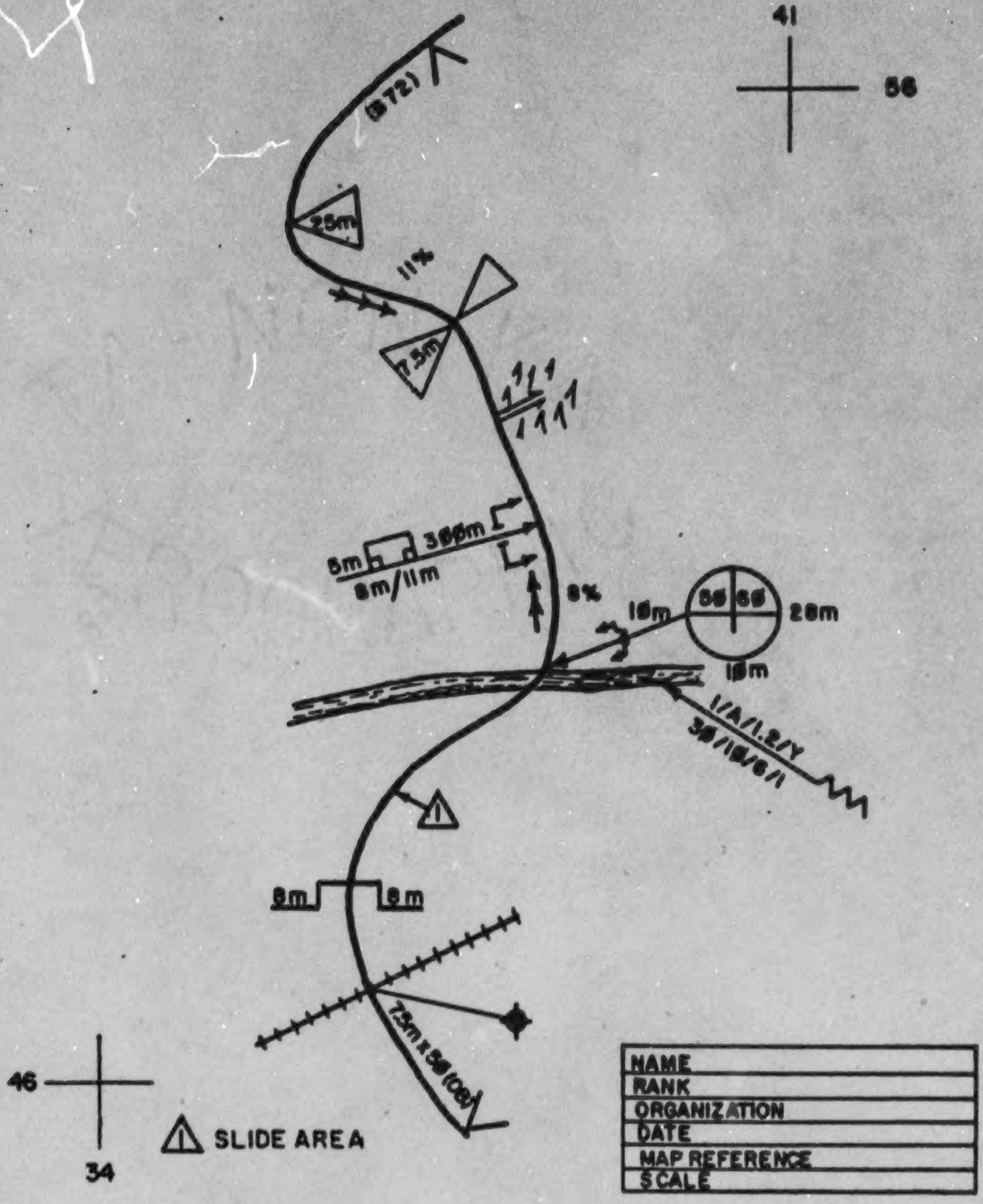
PANEL 6-16

672A

673

PANEL 6-17

ROUTE RECONNAISSANCE OVERLAY


41
56
(B72)
25m
11%
7.5m
300m
5m
8m/11m
8%
10m
50
50
28m
10m
1/A/1.2/Y
30/10/6/1
8m
8m
75m x 50 (08)
46
34
SLIDE AREA
NAME
RANK
ORGANIZATION
DATE
MAP REFERENCE
SCALE

696

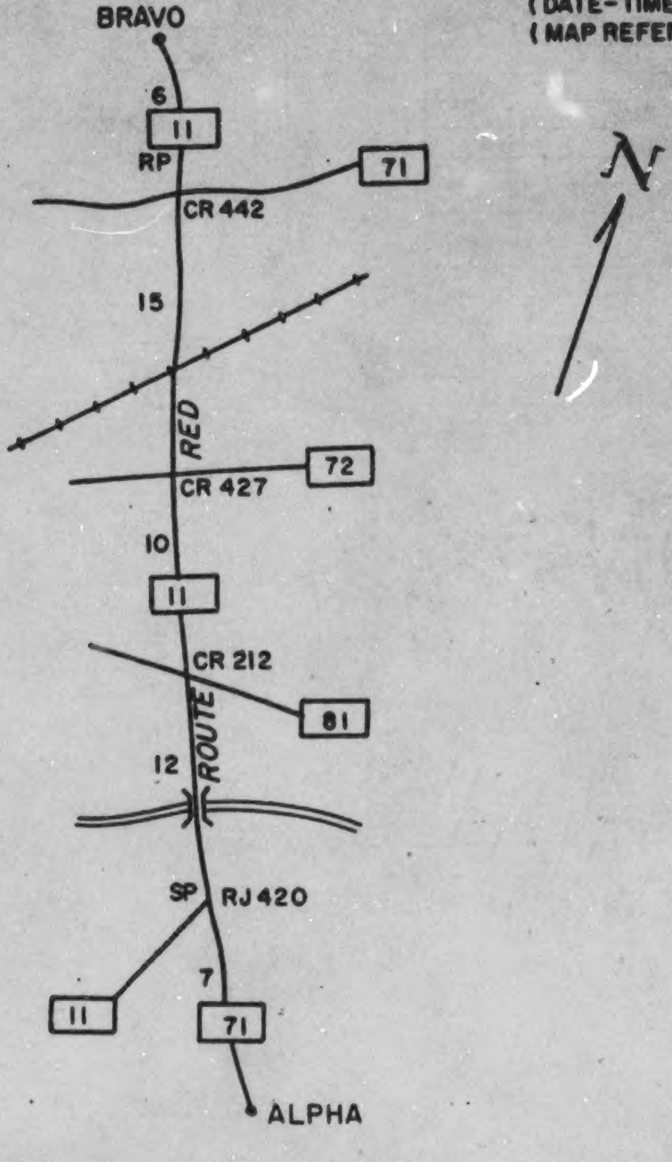
673A

PANEL 6-18

STRIP MAP

(Classification)

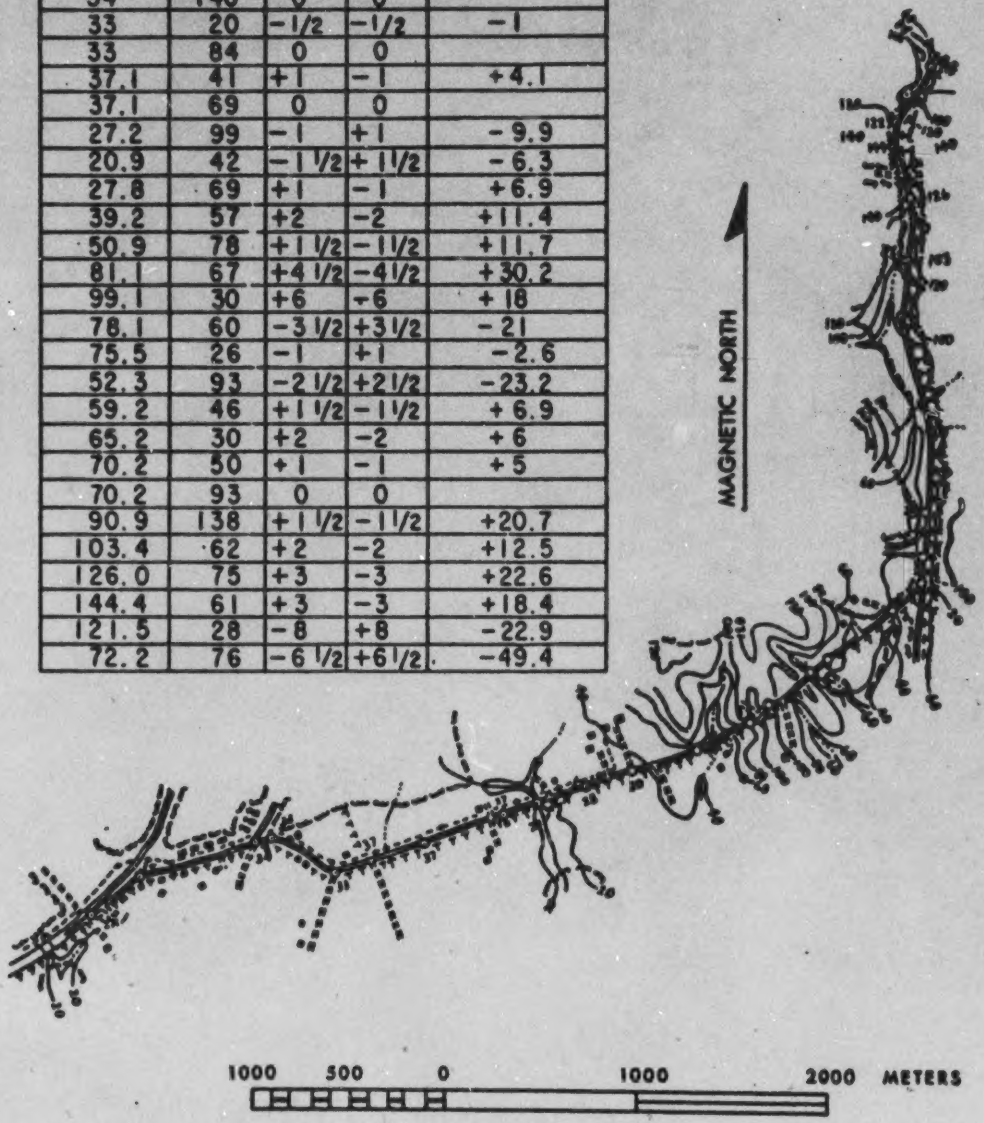
ANNEX ___ TO OPORD ___
(UNIT)
(DATE-TIME GROUP)
(MAP REFERENCE)



BRAVO
6
11
RP
71
CR 442
15
RED
72
CR 427
10
11
CR 212
ROUTE
81
12
SP
RJ 420
7
11
71
ALPHA
N

697

ELEVATION	PACES	CLINOMETER		DIFFERENCE OF ELEVATION
		FORE	BACK	
34				
34	72	0	0	
34	140	0	0	
33	20	−1/2	−1/2	−1
33	84	0	0	
37.1	41	+1	−1	+4.1
37.1	69	0	0	
27.2	99	−1	+1	−9.9
20.9	42	−1 1/2	+1 1/2	−6.3
27.8	69	+1	−1	+6.9
39.2	57	+2	−2	+11.4
50.9	78	+1 1/2	−1 1/2	+11.7
81.1	67	+4 1/2	−4 1/2	+30.2
99.1	30	+6	−6	+18
78.1	60	−3 1/2	+3 1/2	−21
75.5	26	−1	+1	−2.6
52.3	93	−2 1/2	+2 1/2	−23.2
59.2	46	+1 1/2	−1 1/2	+6.9
65.2	30	+2	−2	+6
70.2	50	+1	−1	+5
70.2	93	0	0	
90.9	138	+1 1/2	−1 1/2	+20.7
103.4	62	+2	−2	+12.5
126.0	75	+3	−3	+22.6
144.4	61	+3	−3	+18.4
121.5	28	−8	+8	−22.9
72.2	76	−6 1/2	+6 1/2	−49.4



ROAD SKETCH, INCLUDING FIELD NOTES

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STUDENT PAMPHLET

COMPILATION FROM MAP SOURCES "PULL - UPS"

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

NOVEMBER 1975

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

This material is presented primarily for use at the Defense Mapping School and does not necessarily reflect official United States doctrine. It is designed as a guide to a general method of preparing "Pull-Ups."

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1. INTRODUCTION

This pamphlet is to provide information to supplement the instruction on the Pull-up method of map revision. Pull-ups are normally prepared in conjunction with the Reduction Method of Compilation from Map Sources when the amount of reduction required would cause the detail to coalesce at the new scale.

2. BACKGROUND

Compilation from Map Sources is the compilation of new maps or the revision of existing maps using source maps as the sole means of obtaining information.

The procedures used to prepare a manuscript differ according to the project and the availability of source materials. Basically, however, there is three methods currently being used by cartographers when faced with compiling a map from existing source maps.

a. One-to-One Method

The One-to-One Method is used when the scale of the source map approximates that of the final compilation. This is more or less a direct tracing of the detail of the source map.

Generally, this method is used when you have very accurate foreign source maps available and they have to be converted to a U. S. series.

Most of the changes will involve symbolization and in some cases contour intervals. As an example, large scale German maps may have a 2.5 meter contour interval. The United States does not generally use this interval, therefore, it would have to be changed, possibly to ten meters, by compiling only every fourth contour.

The One-to-One Method is also used to revise existing maps by using foreign source maps having the same scale and making the necessary additions.

b. Common Scale Method

The Common Scale Method is used when source maps, each of a different scale, are available covering the project area.

Each of the source maps may be designated as the primary source for a particular type of feature. For example, you may use one map for relief and drainage, but it is too old for compiling cultural features. Another newer map, may be a planimetric map, such as a city map, which does not show relief, but is up-to-date as far as culture is concerned. An additional map may be necessary for vegetation features. These source maps need not be at the same scale as the desired new map or even at the same scale as each other.

A compilation manuscript is prepared by compiling the detail from one of the source maps and then the others are enlarged or reduced to fit it. The remaining detail is then compiled. The final compilation is reduced, if necessary to the desired scale of the new map.

It is not good procedure to compile at a smaller than production scale. A manuscript should always be prepared at the same scale or a larger scale than the final production scale. The smaller the scale the less information that is available to the compiler.

c. Reduction Method

The Reduction Method is used to prepare small or medium scale maps using large scale maps as the source materials.

There are two basic ways of compiling a map using this method. The first procedure is to have the source maps reduced through a photographic process to the desired new scale. The result of this process is a film positive. These positives are then paneled to a new base and a manuscript is compiled by pulling up the required detail.

If the amount of reduction is too great, the detail on the original source maps would coalesce or come together to such a degree that it would become unreadable when reduced in scale. In this case, a Pull-up is prepared from the source maps. The pull-ups are then paneled to a new compilation or control base and the final manuscript and associated overlays are then compiled.

3. PULL-UPS

Not all of the detail that appears on the source map can be shown, so the objective of a pull-up is to select only the detail that is desired for the new map. The amount of detail to be selected is dependent upon the final production scale.

When preparing a pull-up there are three factors the compiler must consider. These are:

(1) Scale of the source maps

(2) Scale of the final product

(3) Reduction factor required to reduce or enlarge the detail on the source maps to the final production scale.

The reduction factor can be determined by dividing the scale denominator of the final product by the scale denominator of the source map.

Example:

Final Production Scale - 1:250,000

Source Map Scale - 1:50,000

250,000 ÷ 50,000 = 5 = reduction factor

It can be seen from this that the pull-up that the compiler prepares must be reduced five times. Therefore, all symbols shown on the pull-up should be compiled five times larger than the specifications for the new map in order to compensate for the required reduction.

Example:

The JOG Specifications call for a town circle to be shown .05" in diameter. On a pull-up with a five time reduction factor, town circles should be shown .05" x 5 or .25" in diameter.

The exceptions to this are roads, railroads and drainage features. However, these features must be shown wide enough to ensure that they will be clear and readable.

Another consideration facing the compiler is the displacement of detail and clearance between features. On a final compilation manuscript, the compiler must maintain a minimum clearance between features of .01". On a pull-up requiring a five time reduction, this would mean that a comiler would have to maintain a .05" clearance. In order to accomplish this, he will have to displace features.

Example:

A road and a stream are .03" apart and closely parallel to each other on the source map. The compiler would draw the stream in its true position and displace the road .02" in order to have .05" clearance between these two features. This ensures a clearance of .01" when the pull-up is reduced.

It can be seen from the above example that a feature is displaced only enough to allow the minimum clearance. When it is necessary to displace features, the following guidelines should be used:

(1) Roads

(2) Railroads

(3) Drainage

If a road and railroad are parallel each other, hold the position of the railroad and displace the road; railroad and a stream, hold the stream and displace the railroad, etc.

An exception to this will occur when three or more features are closely parallel. In this case the center feature will be compiled first and the features on each side will be displaced as necessary.

Before a compiler begins to work on a pull-up, he should completely familiarize himself with the specifications that pertain to the new map sheet and adhere to these specfifications when preparing the pull-up. In addition to the specifications, the guidelines and procedures set forth in this pamphlet should be used.

4. GUIDELINES FOR PULL-UPS

The following guidelines for the preparation of Pull-ups should be used in conjunction with the specifications for the new map sheet in the order listed.

a. Marginal Information - Compiled in RED

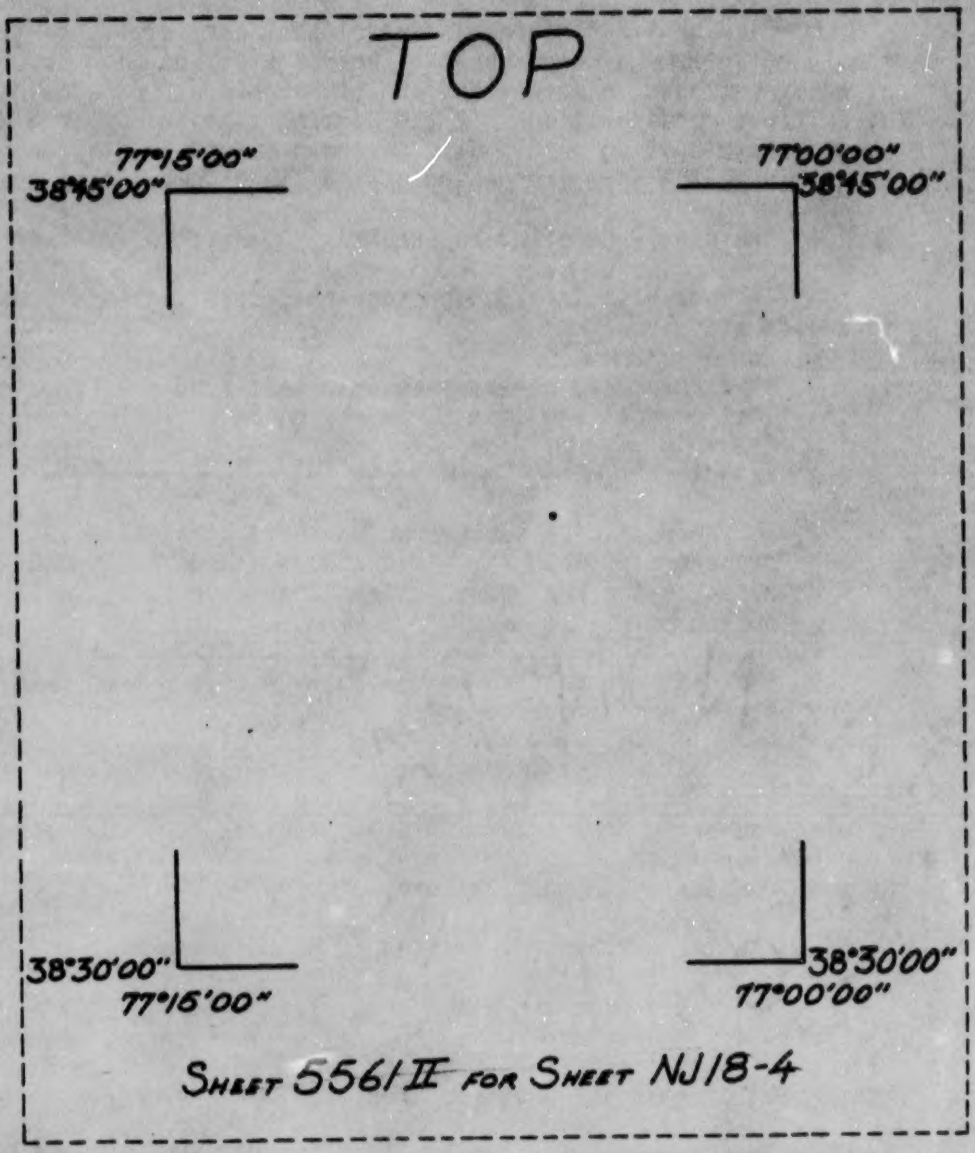
(1) Properly register an overlay to the source map with corner ticks having a line weight of .03" and measuring 2" in length.
9/10

(2) Label the overlay in the SOUTH margin with the sheet number of the source map and the sheet number of the sheet for which the overlay is being prepared.

(3) Label the corners with their geographic coordinates. These values should be .3" high.

(4) Using ~~1~~ 1/2" high letters, label the word "TOP" centered in the NORTH margin.

Example:


TOP
77°15'00"
38°45'00"
77°00'00"
38°45'00"
38°30'00"
77°15'00"
38°30'00"
77°00'00"
SHEET 5561 II FOR SHEET NJ18-4

b. Elevations - Compiled in BLACK

Compile the highest elevation in each quarter of the sheet. Also show an elevation near the center of the sheet. A maximum of five elevations should be compiled for each sheet.

c. Horizontal Control Stations - Compiled in BLACK

Five or six horizontal control stations, evenly distributed should be selected on each sheet. Control stations along boundaries, at prominent road intersections and higher elevations should be given first consideration. If the control station has an elevation on it, the elevation should also be shown. Control stations should be no closer than one inch apart at the final compilation scale.

d. Drainage - Compiled in GREEN

Because blue is a non-photographic color, green is used to depict drainage.

As a rule, all steams measuring less than one inch in length on the final product are omitted on the pull-up.

Example:

> When using a source map having a scale of 1:50,000 to prepare a pull-up for a map at a scale of 1:250,000, no drain on the map measuing less than five inches will be pulled up.

The drainage pattern on the pull-up must be representative of the pattern on the source map.

Open water areas must conform to the specifications at final production scale. For example, the minimum width for a double line drain on a 1:250,000 scale map is .02"; therefore, in order for a stream to qualify as a double line steam on a pull-up at 1:50,000 scale, it must measure .1" wide.

e. Populated Places - Compiled in BLACK

Populated places are the next feature to be compiled on the pull-up. The method and symbolization must be commensurate with the scale of the final product. For medium and small scale maps, town circles and built-up area outlines are generally used.

The largest towns are compiled first. When a populated place qualifies as a built-up area, the outline should include all suburban areas that have a systematic street pattern and a relative concentration of buildings. Do not include, however, outlying scattered buildings. Whenever the outline coincides with a linear feature, the linear feature becomes the outline.

If a populated place does not qualify as a built-up area, a town circle is used. Again the largest towns are compiled first. Town circles should be shown at the approximate center of the towns. If two towns are in close proximity of each other on the source map, the one having the highest military value and that contributes to the best representative pattern should be compiled.

NOTE: On a 1:250,000 scale map, the town circles should be at least one inch apart.

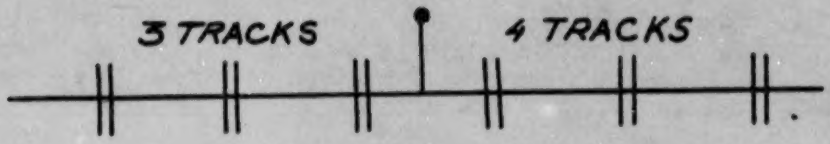
f. Railroads - Compiled in BLACK

Railroads are a very important line of communication and therefore very important on a military map. As much as possible, all railroads should be pulled up with the exception of short sidings.

Railroads are of great military importance and must be shown; however; due to the scale reduction, it may be possible to show only a representive pattern.

A distinction must be made between single and multiple track railroads. If there are more than two tracks, the number of tracks will be labeled along the railroad symbol. When there is a change in the number of tracks, the point of change must be indicated.

Example:

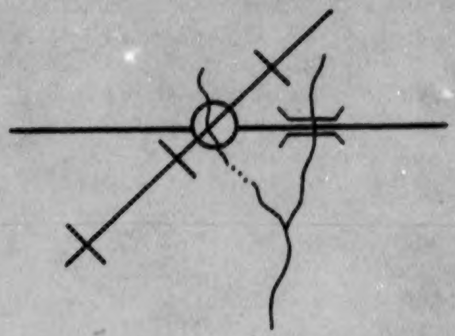


g. Roads - Compiled in RED

The highest classification of roads appearing on the source maps are compiled first. In some foreign areas, the highest classification may only be a fair or dry weather, loose surface road or even as low as a cart track.

When compiling the roads, the compiler should bear in mind that all towns should be connected. Where a town circle is positioned on a road, the road must be broken where it intersects the town circle. Roads are the only feature to be broken for a town circle.

Example:



In built-up areas you need only show a representative pattern of through roads and streets. A through road is a road that will allow you to traverse an area in the most expeditious manner.

h. Miscellaneous Features - Compiled in BLACK

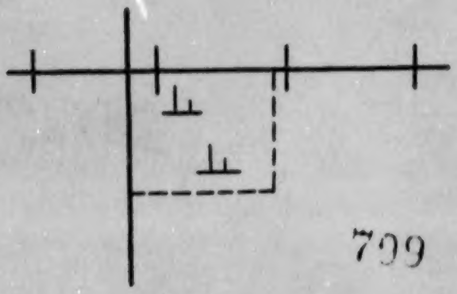
Features of landmark and/or military significance are to be shown in accordance with the specifications for the job being produced.

i. Area Features - Outlined in YELLOW

Area features are features such as vegetation, rice, lava flows, marsh, etc. These are to be compiled only when the area that they encompass measures a minimum of .1" x .1" at the final production scale.

When an area outline coincides with a linear feature, omit the outline.

Example:

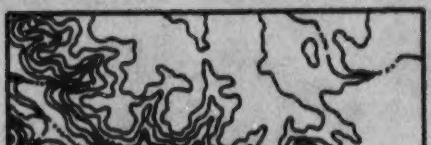


j. Relief - Compiled in BROWN

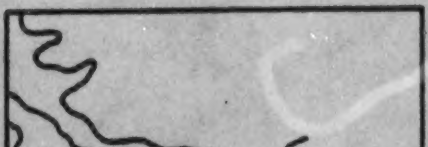
Contours are to be pulled up in accordance with the contour interval specified for the final product. The compiler must distinguish the intermediate and index contours as per the new controur interval.

Due to the reduction involved, the contours must be generalized by smoothing out the curves and eliminating the minute details of the contours. The amount of smoothing that will be required will depend upon how much the pull-up will be reduced; however, the general characteristics and shape of the original contours must be retained.

Example:



CONTOUR INTERVAL 20 METERS
SCALE 1:50,000



CONTOUR INTERVAL 100 METERS
PULL-UP

When pulling up contours, the compiler should ensure that the contours cross all roads at a 90 degree angle and when they cross a double line stream, that they intersect the shoreline at a 90 degree angle.

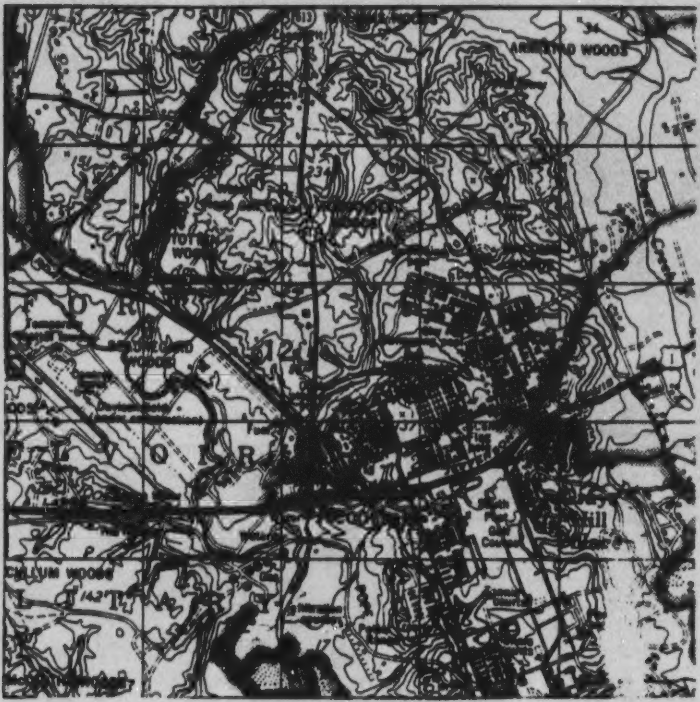
k. Boundaries - Compiled in BLACK (no overprint)

Boundaries are to be shown in accordance with the appropriate specifications.

5. SUMMARY

The pull-up is an expedient method of compiling a small or medium scale map from source maps of a larger scale. All symbolization must be enlarged by multiplying the appropriate symbol size by the amount that the pull-up is to be reduced. The exceptions to this are roads, railroads, and drainage. However, these must be symbolized wide enough to ensure that they will be of a reasonable width when reduced.

The order of compilation prescribed in this pamphlet should be adhered to in conjunction with the specifications peculiar to the project the pull-up is being prepared for.



PORTION OF A MAP AT A SCALE OF 1:50,000

SAME AREA AT A SCALE OF 1:250,000

[illegible]

[illegible]

[illegible]

[illegible] 1974

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

689

ROAD DIMENSIONS

Student Programed Workbook

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INSTRUCTIONS TO STUDENTS

This programmed workbook is a sort of "do-it-yourself" workbook, with built-in instructions and directions. The material is arranged in levels (indicating the location on the page), and each level is further broken down into nine small steps called frames. For each frame, there is an action which requires you to do something; either by filling in a blank space, or other directed action.

This is not a test so don't hurry; take whatever time you need to complete all the frames. The correct response is given just above the start of the next frame. If your response is wrong go back and study the frame until you understand the correct action before proceeding to the next frame. Once a frame is completed and understood, go directly to the next frame.

OBJECTIVES OF THIS WORKBOOK

Upon completion of this workbook, you will be able to do the following:

1. Place all station notes in their correct location

2. Indicate "by note", the points denoting the beginning and ending of construction

3. Dimension the horizontal length of vertical curves

4. Indicate the slope of all straight grade tangents

5. Compute cut and fill notes and place them in their correct locations

6. Plot and dimension ditches

7. Simplify ditch specifications into notes

8. Place ditch elevation markers where required

9. Place culverts and drainpipes in their correct location and show (by note) how they are located

FINAL INSTRUCTIONS

Work all frames in one level before going to another level. (Start Frame 1 = Level A, at top of page 4.)

LEVEL A

1. On Road Drawings, there are specific areas and methods for placement of Notes and Dimensions. The first type we go into are Station Notes. These are placed vertically into the plan-view portion of the paper. Each note should be centered on the station to which it refers.

NOW COMPLETE ACTION 1, AT TOP OF FACING PAGE (Page 5)

LEVEL B

(CUT)

10. Determining Cut and Fill Note (Continued).

Now look at Figure 1, Station 2 + 40; the profile is below the gradeline which indicates a fill. The profile elevation is 497.0' and the gradeline elevation is 501.6'.

LEVEL C

(0+67) (1+30) (+4.3%)

19. Ditch Dimensions:

Ditches are dimensioned by the extension-dimension line method which includes the simplified note (abbreviated ditch specifications) from which that segment was determined.

LEVEL A

ACTION 1.

On your drawing, station notes are placed ____________________ into the plan view portion of the paper and ____________________ on the ____________________ to which they refer.

GO TO FRAME 2, LEVEL A, NEXT PAGE

LEVEL B

ACTION 10.

The difference between the profile and gradeline elevations is ______________ which means that at Station 2 + 40, the depth of __________________ is __________________.

LEVEL C

ACTION 19.

Ditches are dimensioned by the _______________-____________ line method which includes the ________________________ note from which that segment was determined.

LEVEL A

(VERTICALLY), (CENTERED), (STATION)

2. Begin Construction:

This note indicates the point where actual construction on the road begins. It contains information pertaining to the station and elevation where construction begins. (See figure 2, page 23 of this workbook.)

LEVEL B

(4.6') (FILL) (4.6')

11. Grade Notes:

A grade note indicates a station or point along the gradeline where neither cut nor fill is required. (See figure 2, Station 2 + 02 along profile and gradeline.) This is each point where the profile crosses the gradeline. The profile and gradeline elevations at these points will be the same.

LEVEL C

(EXTENSION) (DIMENSION) (SIMPLIFIED)

20. Simplifying Ditch Specifications:

In most instances, it is possible to make a simplified "Ditch Note" rather than copy the whole note. This saves both time and space. However, the simplified version should contain all the pertinent information contained in the original specification.

LEVEL A

ACTION 2.

In Figure 2, the note indicating the beginning of construction should read:

Sta. ______________ begin const.

Elev. ______________

LEVEL B

ACTION 11.

The point where the profile crosses the grade is noted as a ______________ in the cut and fill notes. The elevation at these points is the ______________.

LEVEL C

ACTION 20.

The main reason for making a simplified Ditch Note is to save ____________ and ____________.

LEVEL A

(0+00) (497.0')

3. Notes Regarding Vertical Curves:

These notes indicate the three stations on each vertical curve which must be established in order to locate the curve properly.

These stations are:
(a) Point of Vertical Curvature (PVC)
(b) Point of Vertical Intersection (PVI)
(c) Point of Vertical Tangency (PVT)

These points are hereafter referred to by their abbreviations: (PVC), (PVI), (PVT).

These vertical curve notes contain information pertaining to their station and elevation.

LEVEL B

(GRADE) (SAME)

12. Location of Cut, Fill, and Grade Notes:

The bottom row of the profile paper is allocated exclusively for cut, fill and grade notes. This row will have to be divided into three, equal, vertical spaces in order to accommodate the profile and gradeline and the amount of cut and fill. (See figure 2, page 23.)

LEVEL C

(TIME) (SPACE)

21. Take note "a" of the Ditch Specifications (figure 1, page 22) for example: Note "a" states that a 2' FBD is to be used, that this ditch is existing, and that it's drawn 2.0' below the centerline of the finished grade on the right and left sides of the road. Note "a" when simplified should read "2' FBD 2.0' below ℄ Fin. Gr @ R&L existing."

LEVEL A

ACTION 3.

These notes, (as illustrated in figure 2, page 23) should read:

____________ Sta. ____________

Elev. ____________

____________ Sta. ____________

Elev. ____________

____________ Sta. ____________

Elev. ____________

LEVEL B

ACTION 12.

The bottom row on the profile paper is set aside for ________, ____________ and ____________ notes, and is divided into ____________ equal vertical spaces.

LEVEL C

ACTION 21.

Note "b" of the Ditch Specifications (page 22) when simplified to a Ditch Note should read: ____________, 1.4' ____________ ℄ grade @ ____________ and ____________.

LEVEL A

(PVC) (0+83) (499.5')
(PVI) (2+33) (504.0')
(PVT) (3+83) (490.5')

4. End Construction Note:

This note shows the station and elevation where actual construction on the road ends.

LEVEL B

(CUT) (FILL) (GRADE) (THREE)

13. Cut and Fill and Grade Notes:

A cut and fill note is given for each point on the profile that was plotted on your drawings from the surveyor's profile notes. Grade notes are given for each point where the profile crosses the gradeline. The station of all grade points will be given as illustrated. (See figure 2, Sta. 2 + 02.)

LEVEL C

(2'FBD) (BELOW) (E) (L)

22. Now look at note "c" of the Ditch Specifications (page 22), note "c" tells us that we are to plot two ditch segments, both being on the left side of the road. In dimensioning these two ditch segments, two separate dimensions and notes would be required.

699

LEVEL A

ACTION 4.

As illustrated in Figure 2, this note should read:

Sta.____________ end const.

Elev.________________.

LEVEL B

ACTION 13.

The three elements that make up a cut and fill note are the ________________ elev., the ____________________ elev., and the amount of cut or fill. For grade notes, the word __________________ replaces the amount of cut or fill.

LEVEL C

ACTION 22.

Note "c" of the Ditch Specifications, when simplified, would read (for the first part), + ____ 2'FBD @ ____;
(for the second part) + ____ 2'FBD @ ____.

723

LEVEL A

(5+00) (496.0)

5. Length of Curve:

This is a dimension which indicates the horizontal length of the vertical curve. This dimension shows the horizontal length from the PVC to the PVT.

LEVEL B

(PROFILE) (GRADELINE)

(GRADE)

14. Description of Ditches:

A ditch is shown as a dashed line below the gradeline of the road. This line represents the bottom of the ditch or the flow line (lowest level on which water can flow) elevation. There are twotypes of ditches used in military construction; the "V" bottom ditch (VBD), and the flat bottom ditch (FBD). (See figure on facing page.)

LEVEL C

(+4.3%) (L) (+4.0%) (L)

23. Ditch Elevation Markers:

A ditch elevation marker is a note given for each point where a ditch begins, changes elevation, and ends. This note contains information pertaining to the station and elevation of these points.

701

LEVEL A

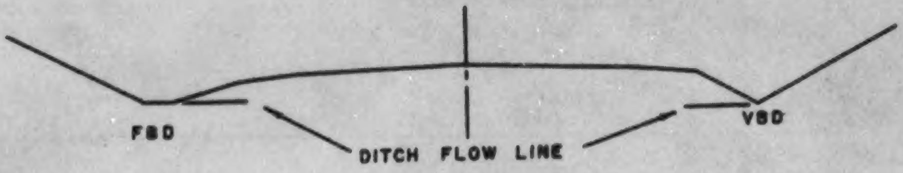
ACTION 5.

In Figure 2, the length of the vertical curve is ___________.

LEVEL B

ACTION 14.

The bottom of a ditch is the ________________ elevation of that ditch.



LEVEL C

ACTION 23.

A ditch elevation marker contains information pertaining to the __________ and ______________ of each point where a ditch begins, changes elevation, and ends.

702

LEVEL A

(300')

6. Percentage of Grades:

The slope of the straight grade tangents is indicated by percent; such as +3%, -3%, +4%, -4%, etc. These figures are placed parallel to, and centered on the tangent to which they refer.

LEVEL B

(FLOW LINE)

15. Plotting Ditches:

Ditches are plotted from notes or specifications which are usually given to the draftsman. Each note represents a segment of a ditch located either on the right (R), left (L), or right and left (R&L) sides of the road. (See figure on facing page.)

LEVEL C

(STATION) (ELELVATION)

24. The ditch elevation marker is drawn in the form of a fraction. (See figure on facing page.) In the figure, the station of the point is the numerator of the fraction and the elevation of the point is the denominator of the fraction.

726

LEVEL A

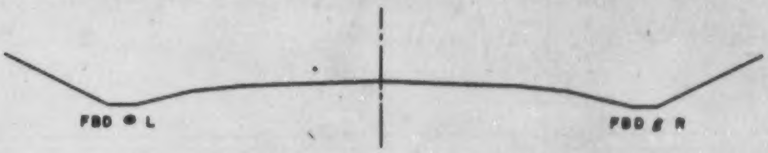
ACTION 6.

In Figure 2, the percentages of the first and second straight grade tangents are __________ and __________.

LEVEL B

ACTION 15.

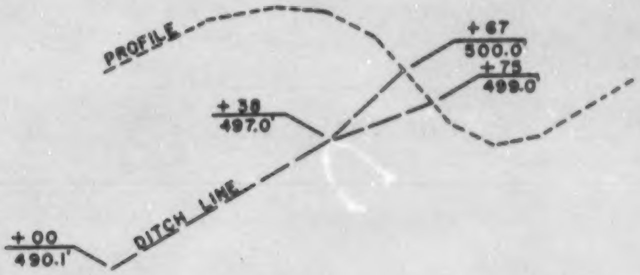
The notation "2'FBD ● R&L" means that there is a 2' __________ on the __________ and __________ sides of the road.



LEVEL C

ACTION 24.

A ditch elevation marker is drawn in a __________ form.


PROFILE
+ 67
500.0
+ 75
499.0
+ 38
497.0'
DITCH LINE
+ 00
490.1'

LEVEL A

(+3.0%) (-3.0%)

7. Cut and Fill:

Cut and fill simply means that in some places along the road project the earth will either have to be cut away or filled in, in order to bring the proposed gradeline to the desired elevation or level as required. (See figure 2.)

LEVEL B

(FLAT BOTTOM DITCH) (RIGHT AND LEFT)

16. The first step in plotting ditches is to find the station and elevation where the ditch begins and ends. This information is obtained from the ditch specifications. (Typical examples shown in figures 1 and 2, pages 22 and 23.)

LEVEL C

(FRACTIONAL)

25. Culverts and Drainpipes:

Culverts and drainpipes are used under roads to carry water, which cannot be diverted with less cost, to natural drainage channels by other means. The types of culverts and drainpipes commonly used in military construction are:

1. CMDP - Corrugated metal drainpipe
2. CP - Concrete pipe
3. BC - Box culvert
4. TBC - Timber box culvert

LEVEL A

ACTION 7.

From Figure 2, we can draw the conclusions that the profile being above the gradeline indicates a ______________ and the profile being below the gradeline indicates a ______________.

LEVEL B

ACTION 16.

Information pertaining to the beginning and ending points of a ditch segment is obtained from the __________ ________________.

LEVEL C

ACTION 25.

A culvert or drainpipe is used to carry water which cannot be diverted by cheaper means, to ________________ ____ __________ channels.

LEVEL A

(CUT) (FILL)

8. Cut and Fill Notes:

Cut and fill notes are notes that show the height of earth-cut (C), or depth of earth-fill (F) at a specific point; say for each plotted point on the profile. These notes are determined from the elevation of the profile and gradeline at noted point.

LEVEL B

(DITCH SPECIFICATIONS)

17. The next step is to find the slope of the segment to be drawn. Note "a" of the Ditch Specifications (see figure 1, page 22) does not give an immediate slope for that particular segment, but it does tell us that the ditch is two feet below the existing road and is, therefore, parallel to the existing road.

LEVEL C

(NATURAL) (DRAINAGE)

26. Location:

A culvert or drainpipe is located by its station and flowline (FL) elevation. (See figure 2.) The station is the centerline of the culvert or pipe, and the flowline elevation is the lowest possible level by which water can flow through the culvert or pipe.

707

LEVEL A

ACTION 8.

Cut and fill notes are given for each ________ point on the ________, and are determined from the elevation of the profile and gradeline.

LEVEL B

ACTION 17.

The set of points equidistant (2' below) from a straight line (the existing road) is a ________ line.

LEVEL C

ACTION 26.

A culvert or drainpipe is located by its __________ and ____________ ____________ elevation.

731

LEVEL A

(PLOTTED) (PROFILE)

9. Determining Cut and Fill Notes:

Look at Figure 2, Station 0 + 00; the elevation of the profile is 500.2' and the elevation of the gradeline is 497.0'. The difference between the two elevations is 3.2'.

LEVEL B

(PARALLEL)

18. Now look at note "c" of the Ditch Specifications (page 22). Note "c" differs from note "a" and note "b"; that is, it gives a slope with which to draw the ditch instead of a distance below the gradeline. This is so because as a practice, parallel ditches are made under the straight portions of the road, and with specific slopes at the curved portions of the road.

LEVEL C

(STATION) (FLOW LINE)

27. Scale:

Culverts and drainpipes are drawn using the vertical scale only. This is to insure that the image of the culvert or pipe will not be distorted.

LEVEL A

ACTION 9.

Since the profile at Station 0 + 00 is above the gradeline, Station 0 + 00 indicates a ____________, 3.2' height.

TURN BACK TO FRAME 10, PAGE 4, LEVEL B

LEVEL B

ACTION 18.

The first part of note "c" of the Ditch Specifications states that a ditch segment is to be drawn from Station __________ to Station ____________ at a slope of ____________.

TURN BACK TO FRAME 19, PAGE 4, LEVEL C

LEVEL C

ACTION 27.

The vertical scale on your drawing is ________________.

You have completed all the frames covering the lesson material "as required" to correctly dimension a road profile and gradeline drawing.

DITCH SPECIFICATIONS

(Frames 15 thru 24)

Ditches are drawn as dashed lines below the gradeline and labelled with an abbreviated specification known as a "Ditch Note"

a. From Station 0 + 00, elev 521.6', plot the existing 2'FBD 2.0' below centerline grade on R&L for a distance of 60' to the left of Station 0 + 00.

b. Beginning at the end of existing ditch, elev 521.6', Sta.0 + 00 plot a 2' FBD 1.4' below centerline grade on R&L to Sta. 0 + 67.47.

c. From Sta. 0 + 67 to Sta. 1 + 30, a 2' FBD, slope +4.3% @ L. From Sta. 1 + 30 to Sta. 1 + 72.5, a 2' FBD, slope +4% @ L. Check elev. at Sta. 1 + 72.5 which is 529.3'.

d. From Sta. 0 + 67.47 to Sta. 1 + 20 a 2'FBD, slope +3.1% @ R. From Sta. 1 + 20 to Sta. 1 + 80, 2 'FBD, slope is +2.5% @ R. Elev. at Sta. 1 + 80 is 528.1'.

e. Plot a 4' FBD @ L. from Sta. 3 + 54 to Sta. 4 + 60.95, at a +2.0% slope. Elev. at 3 + 54 is 531.6'.

f. Plot a 4' FBD @ R from Sta. 3 + 40 to Sta. 4 + 60.95, at a +3.0% slope. Elev. at Sta. 3 + 40 is 530.1'.

g. From Sta. 4 + 60.95, Elev. 533.7', to Sta. 5 + 77 plot a 4' FBD, on the L&R. Slope +0.5%.

h. From Sta. 6 + 68, Elev. 534.4', to Sta. 7 + 70.95 plot a 4' FBD having a -0.5% slope at the L&R.

i. From Sta. 7 + 70.95 to Sta. 8 + 40 at a -1.0% slope, plot a 4' FBD @ R. From Sta. 8 + 40,to Sta. 10 + 11 plot a 4' FBD @ R with a -3.5% slope.

j. At Elev. 533.9', Sta. 7 + 70.95 to Sta. 8 + 40, plot a 4' FBD @ L with a slope of -2.0%. From Sta. 8 + 40 to Sta. 10 + 18, plot a 4' FBD with a -3.5% slope @ L.

k. From Sta. 11 + 17, Elev. 524.8' to Sta. 11 + 24.72 plot a 2' FBD with a +0.35% slope @ the R.

l. From Sta. 11 + 07, Elev. 524.4' to Sta. 11 + 24.72 plot a 2' FBD with a +2.0% slope on the L.

m. From Sta. 11 + 24.72, Elev. 524.8' to Sta. 13 + 00, plot a 2' FBD at R&L with a +0.3% slope. Elev. at Sta. 13 + 00 is 525.3.

FIGURE 1

112

PROGRAMMED LESSON

THE ENGINEER'S SCALE

DEFENSE
MAPPING
SCHOOL
FORT BELVOIR
VIRGINIA

FEB 1976

713

THE ENGINEER'S SCALE

Programmed Lesson

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INSTRUCTIONS TO STUDENTS

This programmed lesson is another of the "self-teaching" booklets. This booklet is arranged similar to the ones you have completed in the past. It is composed of a series of steps or frames that are to be completed before proceeding to the next frame. This booklet is divided into three levels, A, B and C which are to be completed one level at a time.

To work and learn from this booklet, read the left portion of the frame, then over to the right page and complete the response or take the necessary action.

Before going into the practical exercises complete the short self-test, which is designed to see how much of the information you have obtained.

After the self-test you do the practical exercise. Here you will learn to read and use the engineer's scale.

715

OBJECTIVES OF THIS LESSON

Upon completion of this lesson you will know how to use and read the engineer's scale, specifically:

a. Plot measurements from reference points.

b. Obtain a measurement between two points.

c. Read dimensions between given points located on a line.

d. Select the proper scale for each drawing.

e. Understand why some drawings are made either to enlarged or reduced scale.

f. Have a full understanding as to what each division or subdivision, on any given scale, represents on the drawing itself.

FINAL INSTRUCTIONS

Use your engineer's scale and proceed to frame #1. Work through level A before starting level B. After completing level B, continue thru level C, then the self-test. An instructor will be on hand to assist you thru any questionable items.

738

716

LEVEL A

1. The proper use of drafting scales enables a draftsman to lay out proportional dimensions quickly, easily and accurately.

NOW COMPLETE RESPONSE 1, AT TOP OF FACING PAGE

LEVEL B

(TRIANGULAR OR BEVELED)

9. The triangular shaped engineer's scale has the greatest advantage because it has six ratio selections on the one instrument.

COMPLETE RESPONSE 9, LEVEL B

LEVEL C

(DECIMALLY)

17. The engineer's scale is used primarily for civil engineering drawings, such as plot or site, roads, and airfield plans.

COMPLETE RESPONSE 17, LEVEL C

717

LEVEL A

Response 1. A draftsman is able to lay out proportional dimensions ____________, ____________, and ________________ with the the proper use of ______________ __________.

GO TO FRAME 2, LEVEL A, NEXT PAGE

LEVEL B

Response 9. The greatest advantage of the triangular shaped engineer's scale is that it has _____ __________ ______________ in one scale.

GO TO FRAME 10, LEVEL B

LEVEL C

Response 17. The scale that would be used for road construction plans is the ________________ _________

GO TO FRAME 18, LEVEL C

740

LEVEL A

(QUICKLY, EASILY, AND ACCURATELY)
(DRAFTING SCALE)

2. Usually full size drawings are not practical, so therefore the draftsman must make the drawings either to reduced scale or enlarged scale.

COMPLETE RESPONSE 2, LEVEL A

LEVEL B

(SIX RATIO SELECTIONS)

10. The scale is usually made of boxwood with a plastic coating. Care should be taken to protect this plastic coating at all times.

COMPLETE RESPONSE 10, LEVEL B

LEVEL C

(ENGINEER'S SCALE)

18. The standard engineer scale is broken down into units and tenths of a unit.

COMPLETE RESPONSE 18, LEVEL C

719

LEVEL A

Response 2. Drawings are usually made either to _________ _______ or _____________ ____________

GO TO FRAME 3, LEVEL A

LEVEL B

Response 10. The material used to make this scale is _____ _______ with a _____________ _____________ .

GO TO FRAME 11, LEVEL B

LEVEL C

Response 18. When reading a scale of 1″ = 10′ the subdivisions of that inch equal _____ foot.

GO TO FRAME 19, LEVEL C

712

720

LEVEL A

(ENLARGED SCALE OR REDUCED SCALE)

3. A knowledge of the available scales is necessary to ensure that the proper scale is used for a particular job.

COMPLETE RESPONSE 3

LEVEL B

(BOX WOOD) (PLASTIC COATING)

11. Never attempt to transfer a dimension from this scale by placing the dividers directly on the scale. It will scratch or disfigure the facing of the plastic coating.

COMPLETE RESPONSE 11

LEVEL C

(ONE)

19. The units of the standard engineer's scale can represent any unit of measure. For example, a unit can represent one inch, one mile, two hundred feet, or three thousand feet.

COMPLETE RESPONSE 19

LEVEL A

Response 3. The draftsman must be able to select the proper scale for a ______________________ job.

LEVEL B

Response 11. By placing the dividers directly on the scale, you will ______________ or __________________ the coating on the scale.

LEVEL C

Response 19. A unit on the engineer's scale can represent _______ _______ ____ _______________

714

LEVEL A

(PARTICULAR)

4. The four most common types of drafting scales are: Engineer's scale, Architect's scale, Metric Scale, and the Graphic scale.

LEVEL B

(SCRATCH) (DISFIGURE)

12. When cleaning the engineer's scale, use only a slightly dampened towel or cloth and rub softly. Too much water will result in the wood warping or the plastic coating becoming loose.

LEVEL C

(ANY UNIT OF MEASURE)

20. When making a measurement from the scale of 1" = 20', you should select the scale that has 20 subdivisions to the inch.

LEVEL A

Response 4. The ____________ scale, Architect's scale, ____________ scale and Graphic scale are the four most common types of Drafting scales.

LEVEL B

Response 12. The best way to clean the scale is with a ____________ ____________________ towel or cloth.

LEVEL C

Response 20. The scale that has two full units to the inch, has ____ subdivisions to the inch.

LEVEL A

(ENGINEER) (METRIC)

5. When referring to a drawing made to scale, the "scale" is used to indicate the ratio of the size of the view as drawn to the true dimensions of the object.

LEVEL B

(SLIGHTLY DAMPENED)

13. Of the six selections located on the triangular shaped engineer's scale, three can be read from the left end and three can be read from the right end.

LEVEL C

(20)

21. The correct method to make a measurement using the engineer's scale is to place the scale on the drawing, align the scale in the direction of measurement and mark with sharp pencil at desired graduation mark.

LEVEL A

Response 5. The "scale" is used to indicate the __________ of the size of the view as drawn to the ______________________________ of the object.

LEVEL B

Response 13. On the engineer's scale, __________ divisions can be read from the left end and __________ from the right end.

LEVEL C

Response 21. After placing the scale on the drawing and aligning in the direction to be measured, mark the point at the desired ____________ ____________ mark.

726

LEVEL A

(RATIO) (TRUE DIMENSIONS)

6. Enlarged scales may be used when the actual size of the object is so small that full-size representation would not clearly represent the features of the object.

LEVEL B

(THREE) (THREE)

14. The divisions containing the 10, 20, and 30 units to an inch can be read from the left end of the scale, while divisions containing the 40, 50, and 60 units will be read from the right end.

LEVEL C

(GRADUATION)

22. Successive measurements on the same line should be made without shifting the scale. This helps to avoid more chances for error.

749

727

LEVEL A

Response 6. An ______________ view of an object, shows the object at a larger scale than the true dimensions indicate.

LEVEL B

Response 14. By looking at the division that contains 50 units, you would be reading the __________ end of the scale.

LEVEL C

Response 22. To help limit the chances for ____________, as many successive measurements as possible should be made without moving the scale.

750

728

LEVEL A

(ENLARGED)

7. An engineer's scale is divided decimally into ratios or proportions of 10, 20, 30, 40, 50, and 60 parts of an inch.

LEVEL B

(RIGHT)

15. The scale is divided uniformly throughout its length and is classified as full-divided.

LEVEL C

(ERRORS)

YOU HAVE COMPLETED THE FRAMES. AS A SUMMARY REVIEW DO THE SELF-TEST ON PAGES 20 AND 21.

751

LEVEL A

Response 7. The engineer's scale has six ratio selections; they are ____, ____, ____, ____, ____, and ____ parts to an inch.

LEVEL B

Response 15. A full divided scale is divided throughout its ____ ______.

730

LEVEL A

(10, 20, 30, 40, 50, 60)

8. The scale itself can be either triangular shaped or flat with square or beveled edges.

LEVEL B

(LENGTH)

16. Because the scales are divided decimally, the 60 scale, for example, can be used so that one inch equals 6, 60, or 600 feet.

YOU HAVE COMPLETED THE FRAMES. AS A SUMMARY REVIEW DO THE SELF-TEST ON PAGES 20 AND 21.

753

LEVEL A

Response 8. The shape of the scale can be either ______________ or ______________

GO TO FRAME 9, LEVEL B, PAGE 4

LEVEL B

Response 16. The engineer's scale is divided ______________.

GO TO FRAME 17, LEVEL C PAGE 4

732

SELF-TEST

The following self-test is designed for you to see how much of the information you have obtained from this booklet. Solve each problem listed. If you have trouble with any of the problems the number following each problem in parenthesis refers you to the frame from which each problem is taken.

1. A reduced size drawing is made because the object is ______ ______ to draw actual size. (6)

2. By having a full knowledge of all available scales, the draftsman can then select the __________ scale for a ____________________ (3)

3. The four most common types of scales are ______________ scale, ______________ scale, ______________ scale, and ______________ (4)

4. The engineer's scale is divided into _____ divisions. (9)

5. The divisions of an engineer's scale are ___, ___, ___, ___, ___, and ___ parts to an inch. (7)

6. The engineer's scale is usually made of ________ __________ with a ____________________ (10)

7. The engineer's scale should be cleaned with a ______________ ______________ cloth or towel. (12)

8. The three divisions that can be read from the left end of the scale are ___, ___, and ___ (14)

9. The engineer's scale is divided so that ______ units represent one inch using the 50 scale. (16)

10. The engineer's scale is used primarily for ________ __________ drawings. (17)

11. Any unit on the standard engineer's scale can represent ________ ____________________ of measure. (19)

755

733

12. To help avoid errors, ____________________ measurements on the same line should be made without shifting scale. (22)

NOW DO THE PRACTICAL SELF-TEST DESCRIBED

BEGINNING ON PAGE 22

PRACTICAL SELF-TEST

SUBJECT: General Drafting

LESSON: Engineer's Scale

OBJECTIVE: The following exercises are designed for you to apply the information you have learned into solving problems that may be encountered by a construction draftsman.

EQUIPMENT: Engineer's Scale, pencil and paper.

PROBLEMS: Solve the required action on each of the following enclosures as per instructions below:

ENCLOSURE #1

By selecting the proper scale find the length of each line drawn. Place the equivalent length of each line in the space provided at the right of each line.

ENCLOSURE #2

Take the necessary action to complete each of the statements for blocks one through nine.

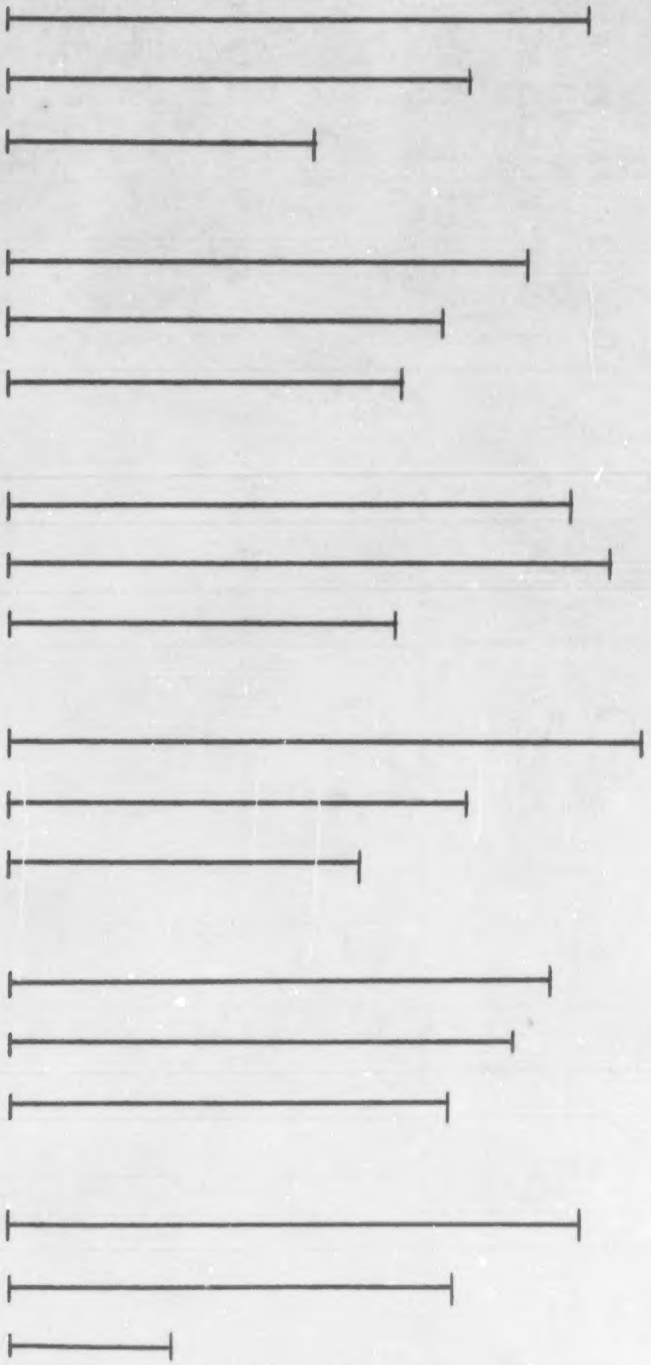
ENCLOSURE #3

Using the scale given, solve the given problems.

734A

CONSTRUCTION DRAFTING
USE OF THE ENGINEER SCALE
PRACTICAL EXERCISE

ENCLOSURE #1



scale **Length**

1"=1,000' ______
______
______

1"=200' ______
______
______

1"=30' ______
______
______

1"=4 miles ______
______
______

1"=500' ______
______
______

1"=60' ______
______
______

758

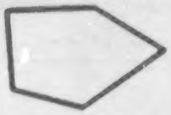
734B

PRACTICAL EXERCISE
ENGINEER'S SCALE

ENCLOSURE #2

24

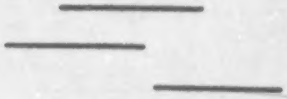
1



THE LENGTH OF THE LONGEST SIDE OF THIS OBJECT IS ____.

SCALE 1" = 30'

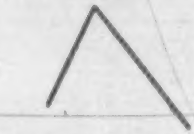
2



THE LENGTH OF THE SHORTEST LINE IS ____.

SCALE 1" = 200'

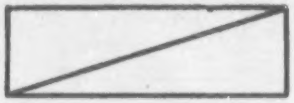
3



IF STRAIGHTENED OUT THE LENGTH OF THIS LINE WOULD BE ____.

SCALE 1" = 1000'

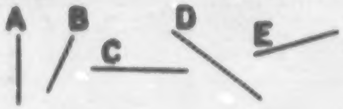
4



THE LENGTH OF THE DIAGONAL LINE IS ____.

SCALE 1" = 50'

5

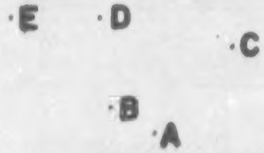


WHICH LINE IS 38' LONG?

A D
B E
C

SCALE 1" = 60'

6



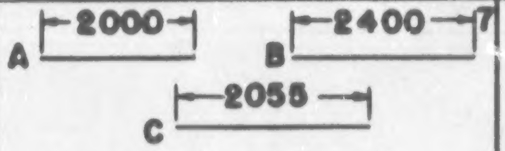
FIND THE DISTANCE BETWEEN THESE POINTS.

A TO E ____ B TO D ____

C TO E ____ A TO D ____

SCALE 1" = 400'

7



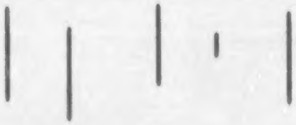
CORRECT ANSWER IS

A ____ B ____

C ____

SCALE 1" = 2000'

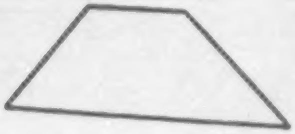
8



THE LENGTH OF THE FIVE LINES ADDED TOGETHER IS ____.

SCALE 1" = 10'

9



THE TOTAL LENGTH OF ALL FOUR SIDES IS ____.

SCALE 1" = 500'

759

734C

ENCLOSURE #3

1-A. The length of the line in #1 is divided into three parts. Using the scale of 1" + 200', find the distance of line ab__________, bc _____________, cd ___________ and the total ______________.

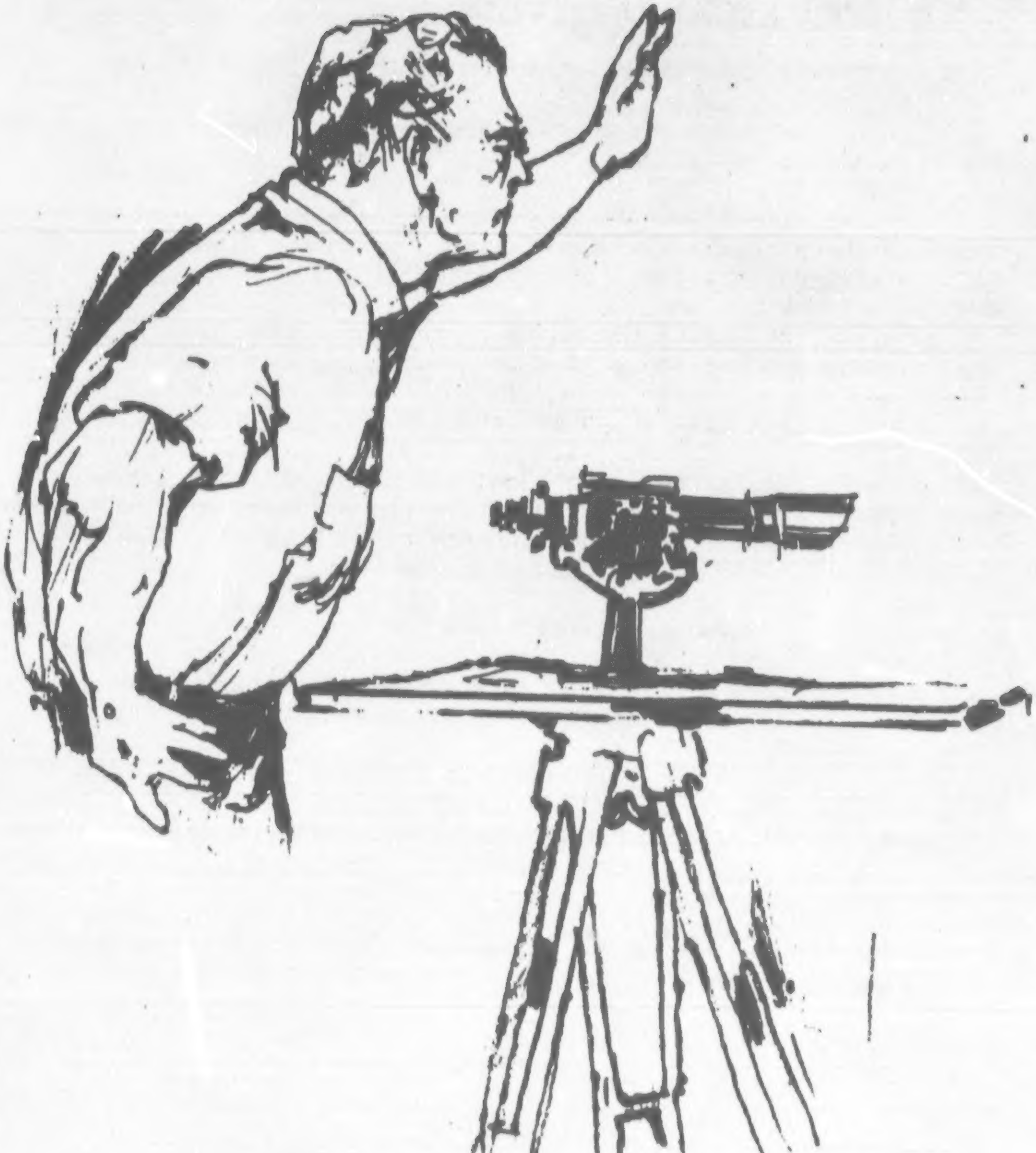
2. Using the scale of 1" = 3', the distance between point a and b equals ______________.

3. The total length of line cd added to ef equals _____________.
Scale: 1" = 400 miles.

735

PLANETABLE

SURVEYING



PLANETABLE SURVEYING

This handout is intended to aid personnel in understanding planetable procedures, even though, only a minimum number of formal hours of instruction have been presented on the subject. It is also intended as a guide for personnel in the field that have been taught planetable procedures but have not had the need to do this type of work over a long period of time.

Any deviation from the procedures set forth here will result in delay and confusion, to the average student, in plotting points and finding their differences in elevation. It is advised that each student study this handout prior to attempting a job in the field.

1. SETTING UP AND ORIENTING THE TABLE

a. Four Steps in Setting Up

Assuming the board and tripod have been properly assembled, the table is set up as follows:

(1) Place the tripod over the given station so that the board is approximately level, oriented, and about waist high. The legs must be well spread, and firmly planted in the ground.

(2) Shift the entire board until the station as plotted on the board is approximately over the station on the ground.

(3) Sink shoes and tighten tripod wing-nuts.

(4) With the Johnson Head upper wing-nut loose, level the board by eye and clamp lightly. Place the alidade over the center of the table and refine the leveling with the aid of the circular bubble on the alidade base. Hold the alidade with one hand until leveling is completed.

b. Orientation of the Table

There are several methods of orienting the table, some of which will be discussed later. The principal method is backsighting.

(1) Set the edge of the alidade in such a position that it passes through the point of the sheet that represents the station occupied and also through a second point that represents some other station or some object that can be used as a backsight. The backsight station must have already been plotted on the planetable sheet.

(2) Rotate the board until the line of sight is directed to the backsight and clamp the board in the position with the lower Johnson Head screw.

2. STEPS IN LOCATING AND PLOTTING A POINT

a. A pin is normally placed in the sheet representing the station occupied. Place the working edge of the alidade against the pin and sight the alidade on any other point which is to be plotted on the sheet.

b. Obtain height of instrument (HI) by measuring from the ground to the horizontal line of sight.

c. Determine if a level sight shot can be made.

d. Remove parallax and focus on rod, sit middle hair as near to the HI on the rod as possible, then turn the vertical motion screw so that one of the stadia hairs is in coincidence with one of the even foot or half foot marks on the rod.

e. Record rod intercept (Stadia Distance).

f. Level Beaman Arc Bubble and turn the vertical slow motion screw until the Vertical Scale Index is in exact coincidence with the nearest whole Beaman Step.

g. Read the Beaman Step and "H" scale, read the CCI.

h. Multiply "H" by Rod Intercept to obtain correct horizontal distance.

i. Measure the corrected distance with the Engineer's Scale and plot position along straight edge of alidade. Plot the point observed as a dot.

j. By the time the point has been plotted on the sheet the recorder should have the elevation computed.

k. Write the elevation of the point on the sheet using the plotted point as a decimal. Arrange all elevations and other lettering so as to read from one direction.

3. MOVING TO THE NEXT STATION OR SET-UP

a. Determine whether you should move to next station or to a temporary point.

b. When satisfied nothing more can be accomplished move to next station, sight back on station just occupied and continue in the same procedure.

4. CARE OF THE INSTRUMENT

a. Never manipulate board without grasping instrument with one hand.

b. Always place instrument in carrying case if not in use.

c. Notify instructor if there is any malfunction of instrument.

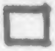
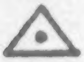
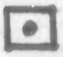
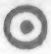
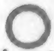
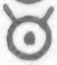
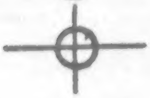
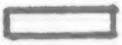
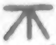
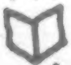
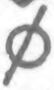
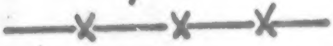
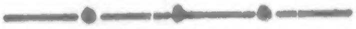
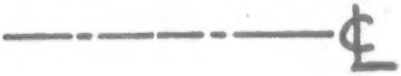
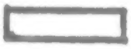
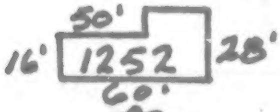
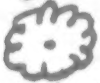
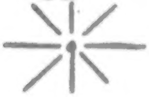
d. Students should not make any adjustments themselves.

e. Do not put any oil on any of the moving parts.

(2) Abbreviations

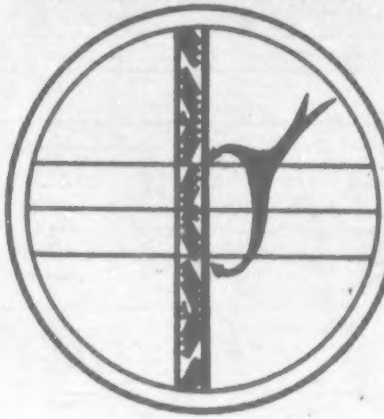
Station	STA	Grade	GD
Manhole	M.H.	Ground	GND
Culvert	CULV	Bench mark	B.M.
Drop inlet	D.I.	Temporary bench mark	T.B.M.
Telephone pole	TEL POLE	Turning point	T.P.
Headwall	HDW	Stake	STK.
Concrete	CONC.	Monument	MON.
Building	BLDG.	Spike	SPK
Road	RD.	Curb	CB.
Street	ST.	Center	C.
Highway	HWY	Centerline	℄

(1) Symbols

 BM	Bench mark
	Triangulation station
	Stadia station
	Transit traverse station
	All poles (indicate type)
	Fire hydrant
	Man holes (indicate size and composition of cover)
	Drop inlets
	Instrument
	Recorder (Notekeeper)
	Rodman
	Barbed wire
	Chicken wire
	Centerline of roads or streets (indicate name)
	Culvert headwalls (indicate size and composition)
	Buildings (show general shape and record number and dimensions
	Deciduous trees (indicate diameter)
	Coniferous trees (indicate diameter)

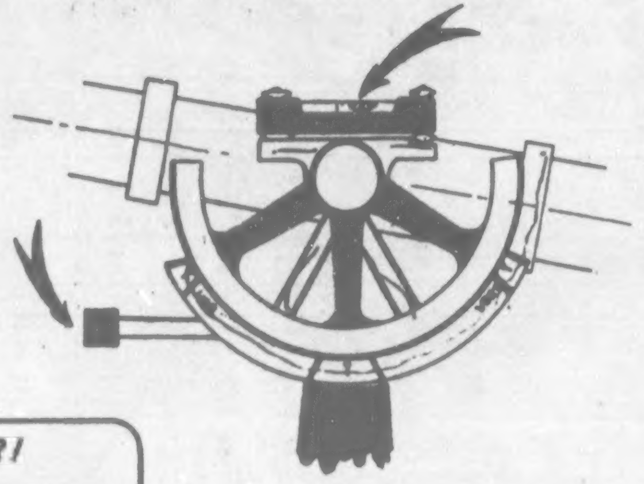
5.

SIGHT ON STADIA ROD AND CALL ROD INTERCEPT AS ".96".



1.

AFTER CALLING ROD INTERCEPT, IMMEDIATELY LEVEL THE BEAMAN ARC BUBBLE

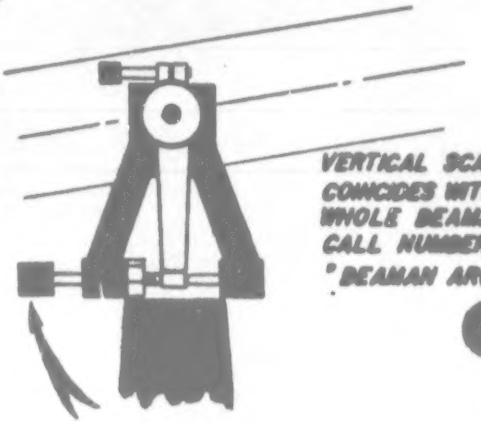


2.

REMEMBER!

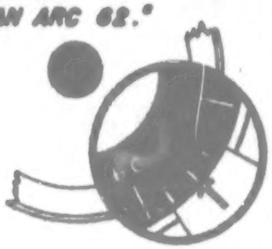
1. READ ROD INTERCEPT
2. LEVEL BEAMAN ARC BUBBLE
3. COINCIDE ARC & VERTICAL INDEX TO WHOLE BEAMAN
4. SIGHT AGAIN FOR CENTER CROSSHAIR INTERCEPT

3.

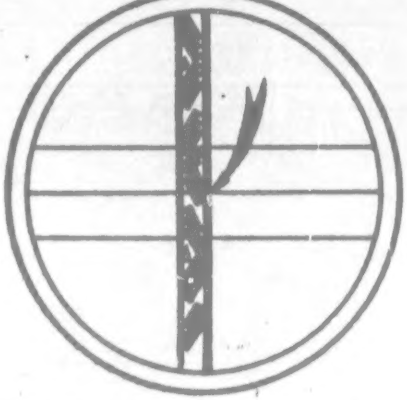


THEN, ADJUST THE SLOW MOTION SCREW UNTIL -

VERTICAL SCALE INDEX COINCIDES WITH THE NEAREST WHOLE BEAMAN NUMBER. CALL NUMBER AS - "BEAMAN ARC 62."



4.



SIGHT THROUGH SCOPE AGAIN, CALL OUT CENTER CROSSHAIR INTERCEPT -

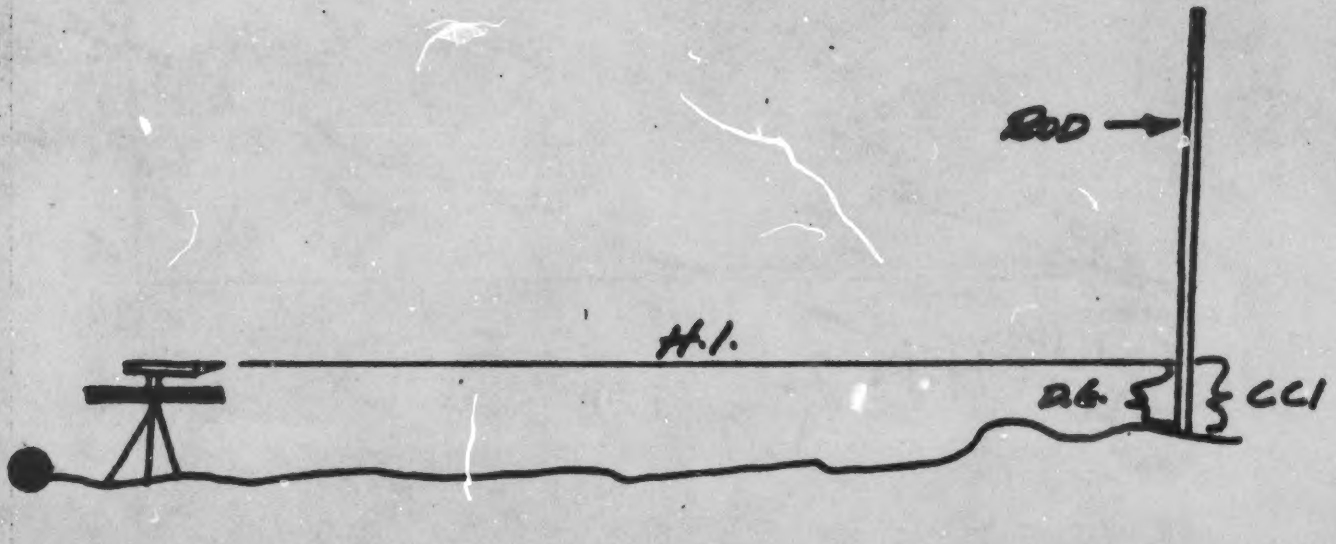
LEVEL OBSERVATION

TO ESTABLISH ELEVATION ON OBSERVED POINT (F.S.)

a. NO PRODUCT AS "V" SCALE READS 50
b. CCI IS MINUS (—)
c. CCI EQUALS DE (MINUS)

CCI MINUS IN SIGN BRINGS INFORMATIO "DOWN" FROM HI TO ELEVATION OF POINT OBSERVED.

R.I.	∨ SCALE	PROD ±	CCI	DE ±	HI	ELEV
2.55	50	—	-5.4	-5	116.7	



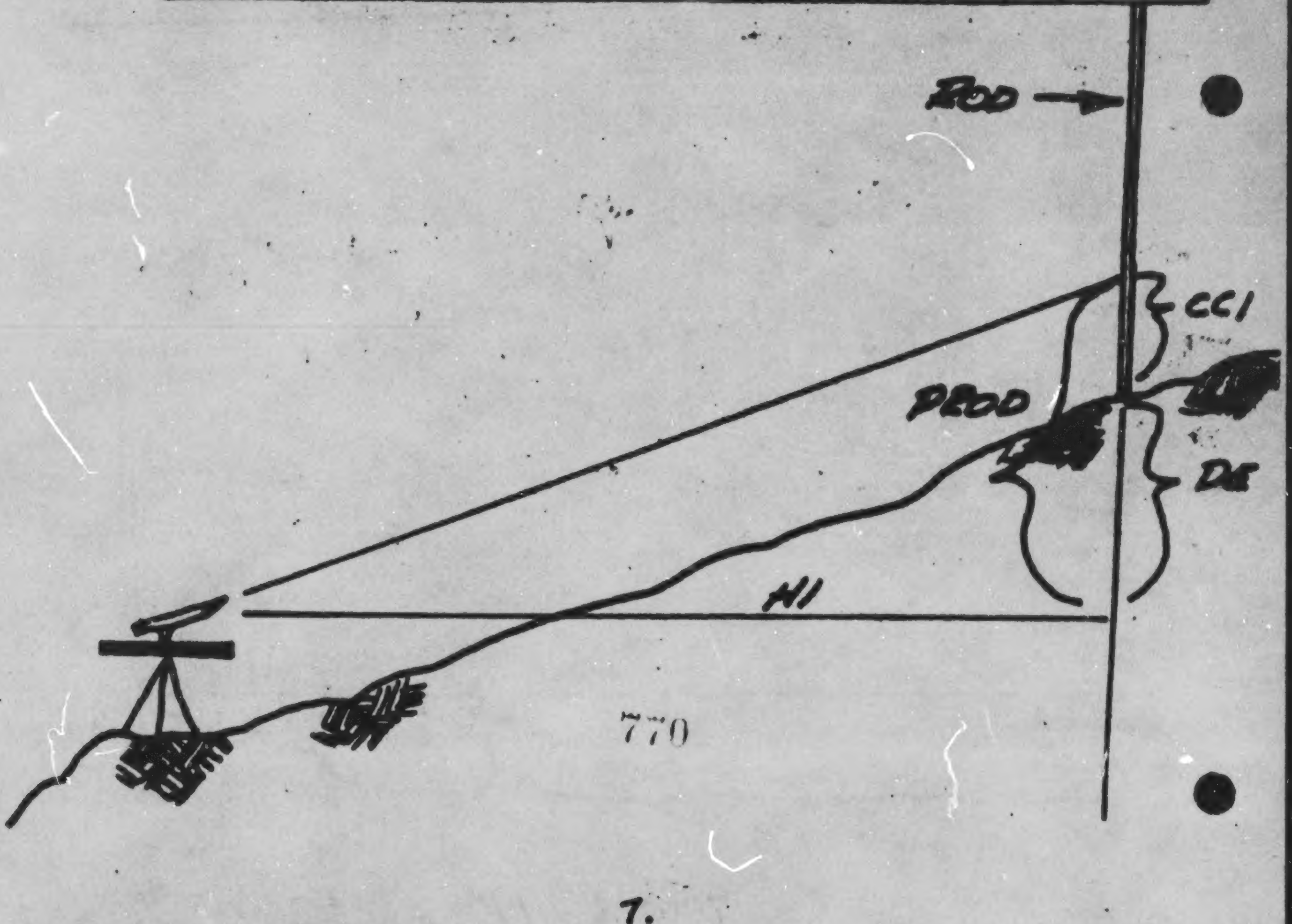
INCLINED OBSERVATION (UPHILL)

TO ESTABLISH ELEVATION ON OBSERVED POINT (F.S.)

a. PRODUCT IS POSITIVE (+) ABOVE 50 ON "V" SCALE
b. CCI IS MINUS (−)
c. PRODUCT PLUS CCI (ALGEBRAICALLY) EQUALS D.E. (PLUS IN SIGN)

A POSITIVE DE BRINGS INFORMATION "UP" __FROM__ HORIZONTAL PLANE OF INSTRUMENT TO ELEVATION OF OBSERVED POINT.

R.I.	V SCALE	PROD ±	CCI	DE ±	HI	ELEV
6.25	55		-4.6		116.7	



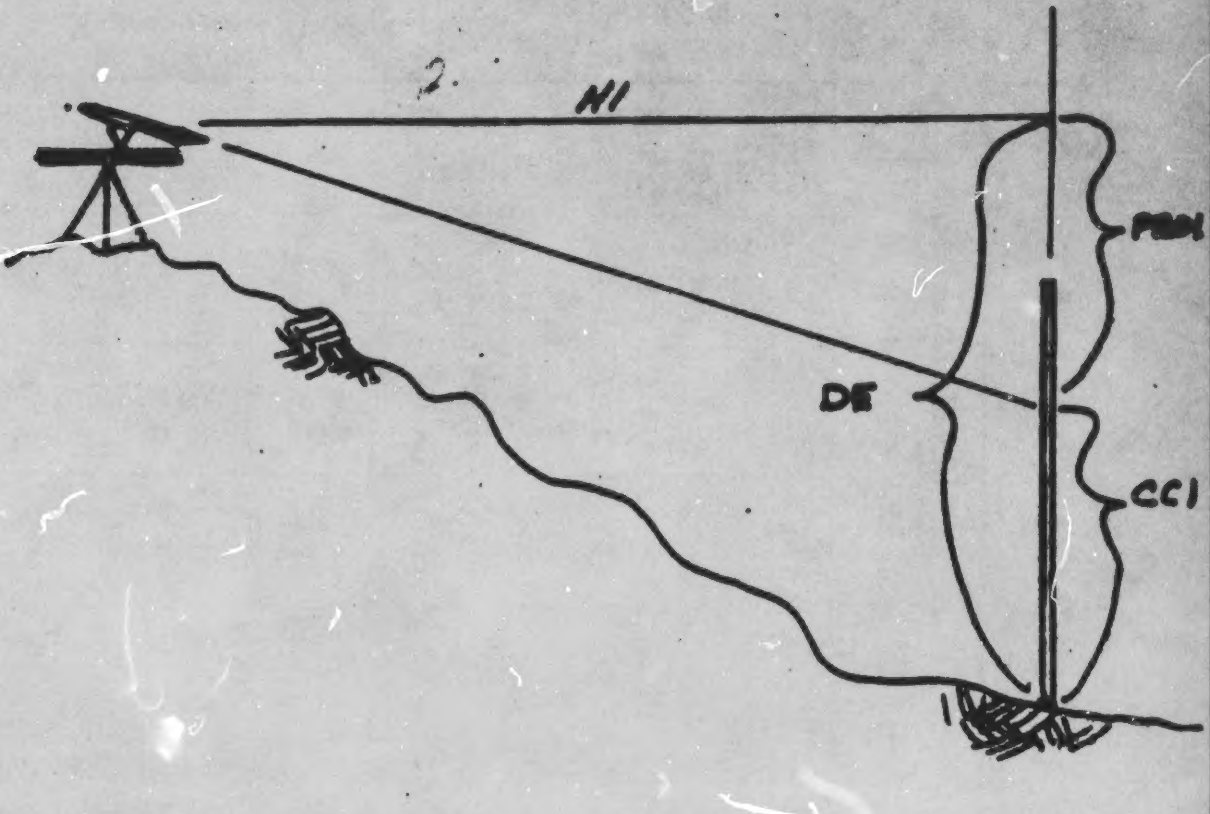
DEPRESSED OBSERVATION (DOWNHILL)

TO ESTABLISH ELEVATION ON OBSERVED POINT (F.S.)

a. PRODUCT IS MINUS (–) BELOW 50 ON "V" SCALE
b. CCI IS MINUS (–)
c. PRODUCT PLUS CCI (ALGEBRAICALLY) EQUALS DE (MINUS IN SIGN)

CCI AND PRODUCT BOTH MINUS (–) IN SIGN BRINGS INFORMATION "DOWN" FROM HI TO ELEVATION OF OBSERVED POINT.

R.I.	V SCALE	PROD ±	CCI	DE ±	HI	ELEV
2.45	37		-7.5		116.7	



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⊼ McGEEHAN	PROJECT PLANETABLE MAPPING	WEATHER SUNNY	GENERAL SURVEY NOTES
Ʊ WHITE	LOCATION FT. BELVOIR, VA	WIND N 4	INSTRUMENT K&E ALIDADE — DATE 10 MAY 76
ϕ SPERGER	DESIGNATION	TEMP 64°F	ORGANIZATION DEF MAP SCH — PAGE NO. 1 — NO OF PGS 4

STA	CORR H. DIST	H SCALE	R.I.	V SCALE	PROD ±	CCI −	D.E. ±	H.I.	ELEV	REMARKS
A							+4.3	116.7	112.4	ELEV STA A
1	625	100	6.25	55	+31.2	4.6	+26.6		143.3	TOP OF SLOPE
2	160	100	1.60	48	−3.2	2.8	−6.0		110.7	BOTTOM OF SLOPE
3	199	97	2.05	68	+36.9	8.4	+28.5		145.2	℄ ROAD
4	368	98	3.75	62	+45.0	7.2	+37.8		154.5	℄ ROAD
5	105	100	1.05	54	+4.2	3.9	+0.3		117.0	SPOT ELEV
6	425	100	4.25	47	−12.8	4.4	−17.2		99.5	SPOT ELEV
7	240	98	2.45	37	−31.8	7.5	−39.3		77.4	MANHOLE
8	255	100	2.55	50	0	5.4	−5.4		111.3	POWER POLE
9		100	3.65	52		6.7				18" CULVERT
10		99	0.85	58		4.3				WATER VALVE
11		99	4.55	61		7.6				EDGE OF ROAD
12		100	2.20	50		3.1				" " "
13		97	2.85	33		8.4				" " "
14		100	6.70	54		5.2				COR PARK LOT
15		99	3.35	40		6.4				" " "
16		99	1.70	38		4.1				EDGE OF ROAD
17		100	5.10	47		8.2				18" CULVERT
18		100	4.40	55		5.6				POWER POLE

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⊼ SFC CLARK	PROJECT 1FY77 | US | PLA | H | 77	WEATHER COLD, CLEAR, CALM	**GENERAL SURVEY NOTES**
Ʊ SPS SPERGER	LOCATION FT. BELVOIR, VA	WIND N 10	INSTRUMENT K&E ALIDADE #16743 · DATE 01 FEB 77
Ø CPL MORSON	DESIGNATION PE #1	TEMP 24°F	ORGANIZATION DEF MAP SCH · PAGE NO. 2 · NO. OF PGS. 4

STA	CORR H. DIST	H SCALE	R.I.	V SCALE	PROD ±	CCI −	D.E. ±	H.I.	ELEV	REMARKS
A							+4.4			ELEV STA A
1		100	2.60	50		-4.3				
2		100	3.30	50		-7.6				
3		100	1.25	50		-4.6				
4		100	1.00	50		-5.5				
5		100	1.05	50		-7.5				
6		100	2.31	50		-8.6				
7		100	1.82	47		-3.3				
8		100	2.10	45		-5.8				
9		100	2.81	45		-5.1				
10		99	2.52	43		-6.4				
11		99	1.73	43		-6.2				
12		100	0.72	49		-4.8				
13		100	0.71	49		-4.4				
14		100	2.12	50		-7.4				
15		100	1.91	51		-2.1				
16		100	1.06	49		-2.9				
17		100	1.14	50		-8.5				
18		100	2.12	52		-9.8				
19		100	2.36	51		-9.9				

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T SFC CLARK	PROJECT 1FY77/US/PLA/H/77	WEATHER COLD, CLEAR, CALM	**GENERAL SURVEY NOTES**
SP5 SPERGER	LOCATION FT. BELVOIR, VA	WIND N 10	INSTRUMENT K&E ALIDADE #16143 — DATE 01 FEB 77
CPL MORSON	DESIGNATION P.E. # 2	TEMP 24° F	ORGANIZATION DEF MAP SCH — PAGE NO. 3 — NO. OF PGS. 4

STA	CORR H. DIST	H SCALE	R.I.	V SCALE	PROD ±	CC1 −	DE ±	H.I.	ELEV	REMARKS	
B							+4.6		118.6	ELEV	STA B
1		99	1.67	52		-4.7					
2		96	2.51	67		-6.9					
3		97	3.12	65		-7.4					
4		100	3.16	50		-8.8					
5		100	2.91	51		-7.2					
6		100	1.87	52		-5.0					
7		98	1.65	56		-9.7					
8		100	1.46	50		-11.1					
9		99	1.64	54		-4.4					
10		100	2.02	53		-7.8					
11		100	2.10	52		-6.4					
12		98	2.54	60		-12.3					
13		100	2.61	50		-10.6					
14		99	2.78	55		-9.9					
15		100	3.10	53		-8.6					
16		97	2.97	60		-8.2					

776

777

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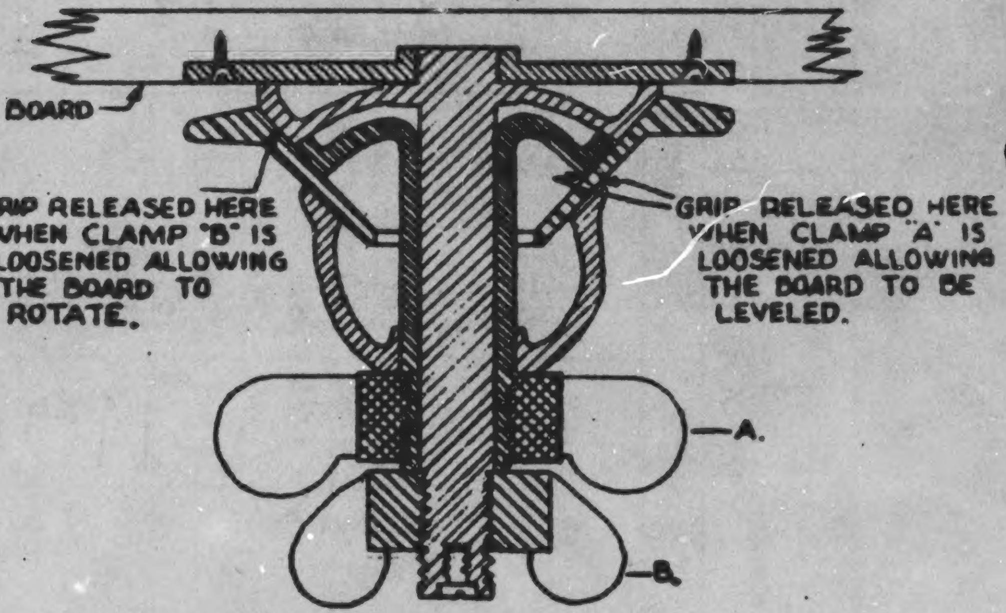
⊼ Ɐ ø P. E.	PROJECT LOC ~~#~~ # 1 DESIGNATION	WEATHER WIND TEMP	GENERAL SURVEY NOTES INSTRUMENT / DATE ORGANIZATION / PAGE NO. 4 / NO OF PGS 4

STA	CORR H. DIST	H. SCALE	R.I.	V SCALE	PROD ±	CCI −	DE ±	H.I.	ELEV	REMARKS
B							+4.6		118.6	ELEV STA B
1		99	1.67	52		4.7				
2		96	2.51	67		6.9				
3		97	3.12	65		7.4				
4		100	3.16	50		8.8				
5		100	2.91	51		7.2				
6		100	1.87	52		5.0				
7		98	1.65	56		9.7				
8		100	1.46	50		11.1				
9		99	1.64	54		4.4				
10		100	2.02	53		7.8				
11		100	2.10	52		6.4				
12		98	2.54	60		12.3				
13		100	2.61	50		10.6				
14		99	2.78	55		9.9				
15		100	3.10	53		8.6				
16		97	2.97	60		8.2				

12.

778

779


BOARD
GRIP RELEASED HERE WHEN CLAMP "B" IS LOOSENED ALLOWING THE BOARD TO ROTATE.
GRIP RELEASED HERE WHEN CLAMP "A" IS LOOSENED ALLOWING THE BOARD TO BE LEVELED.
A.
B.

CROSS-SECTION OF THE JOHNSON HEAD

412-110-B-030-010

PROGRAMMED LESSON

CONSTRUCTION SURVEYING COURSE

PLANETABLE CONTOURING

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

OCTOBER 1974

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

TO THE STUDENT

This programmed lesson is essentially a workbook. The lesson information is broken into small sequential units called frames, which enable you to make an active response.

Study each frame carefully and complete each response. The correct response will be found on the page following each frame, There is no answer sheet. Do not proceed to the next frame until you have mastered all the information in the present frame. An instructor will assist you if the need arises.

This booklet is your property. Do all your work in the spaces provided. This is not a test and will not be graded. However, the Practical Exercise will be collected and evaluated to determine how well you have met the objectives. The self-tests are designed to summarize units of instruction and provide a means whereby you can measure how well you are learning the information and will not be graded.

A total of 5 hours is allotted for the lesson and P.E. You may work at your own pace. Begin with Frame #1 on page 1.

STATEMENT OF OBJECTIVES

The purpose of this lesson is to provide you with the knowledge and ability required to prepare contour maps in the field. In a previous lesson you learned the principles of elevation and relief, some of which are basic to logical contouring. This lesson is designed to enable you to:

A. DEFINE A CONTOUR

1. Recognize the difference between elevation and relief.
2. List the characteristics of contour lines (8).
3. Define the types of contour lines.
4. Define contour interval.

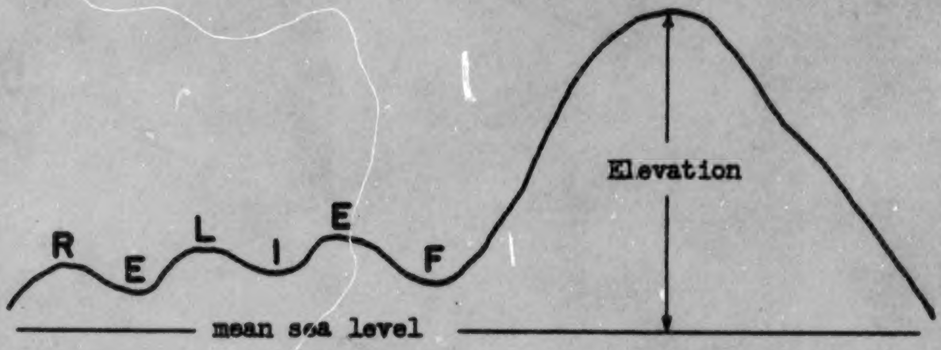
B. SKETCH CONTOURS ON A PLANE TABLE SHEET

1. Determine elevations at stream junctions.
2. Determine where contours cross streams and sketch in the contours.
3. Determine and sketch in ridge line locations.
4. Determine where contours cross ridge lines and sketch in the contours.

FRAME #1

In any type of mapping it is essential to understand the difference between elevation and relief.

The distinction is a simple one. Elevation refers to the height of a point above or below mean sea level, while relief refers to the general shape of the ground.



RE: The height of a point above or below mean sea level is its ________. The shape of the ground is its ________________.

Do elevations show relief? ________

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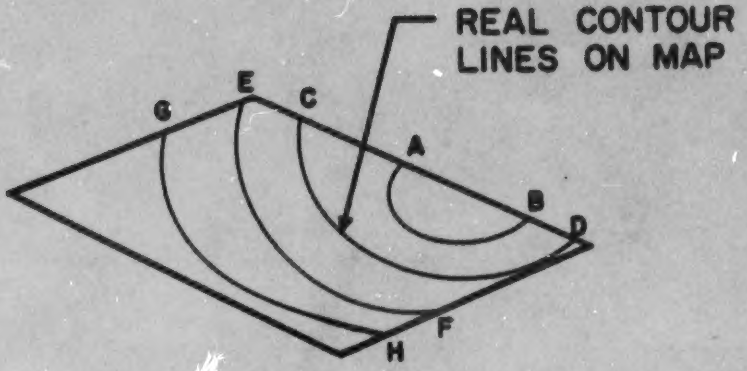
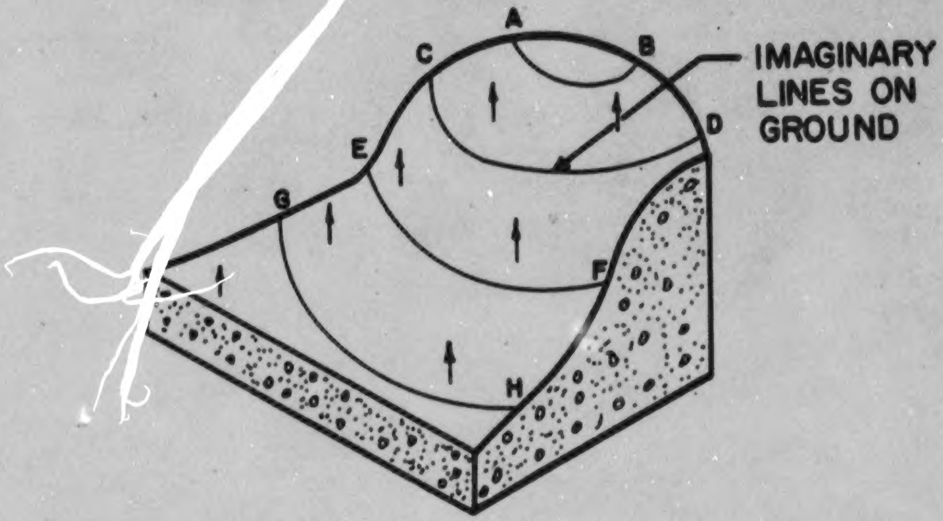
ANS: Elevation, relief, yes

FRAME #2

A contour line is a line on a map that represents an imaginary line on the surface of the earth along which all points lie at the same elevation. Mean sea level is the starting point or "0" elevation.


REAL CONTOUR LINES ON MAP
G
E
C
A
B
D
F
H


A
B
C
IMAGINARY LINES ON GROUND
D
E
G
F
H

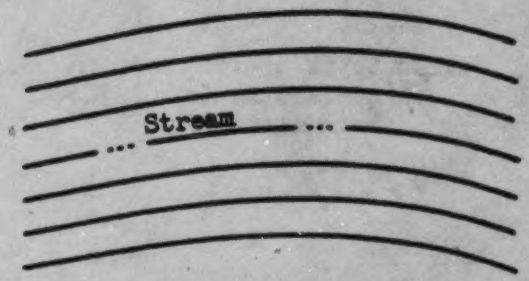
RE: Any line connecting a series of points of equal elevation can properly be called a ________ line.

ANS: Contour

FRAME #3

Contour lines possess eight (8) fundamental characteristics. The first three of these are:

1. Contours tend to parallel each other and tend to parallel streams, or man made features such as railroads.



2. Contours never cross or touch except at overhanging or vertical cliffs and at waterfalls.

3. Contours never fork.

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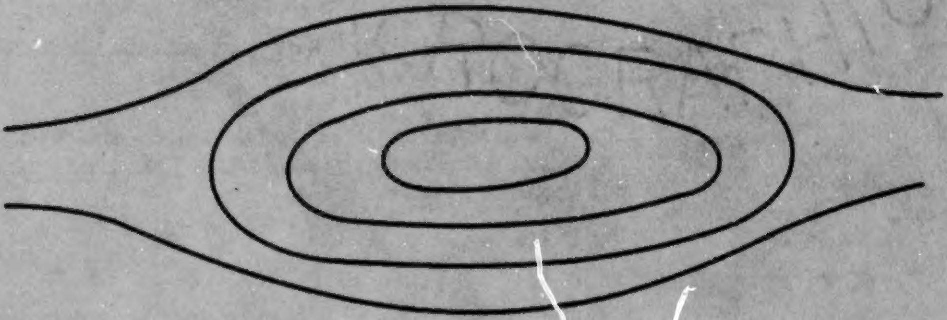
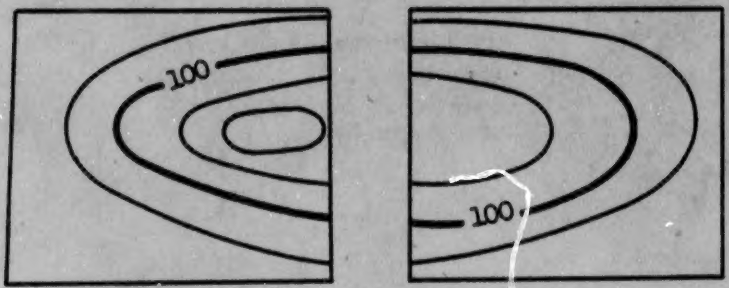
FRAME #4

Characteristics 4 and 5 are:

4. Contours form smooth natural curves.



5. Contours always close on themselves either inside or outside the limits of your map sheet.



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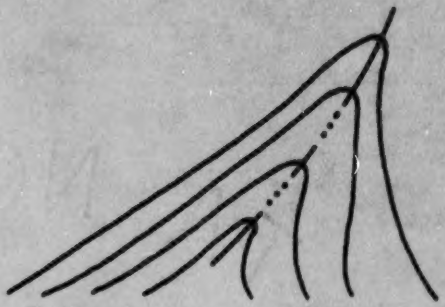
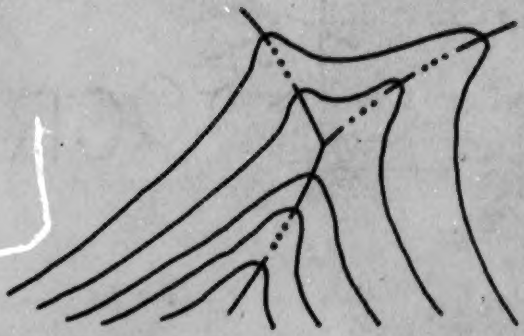
FRAME #5

The remaining three characteristics are:

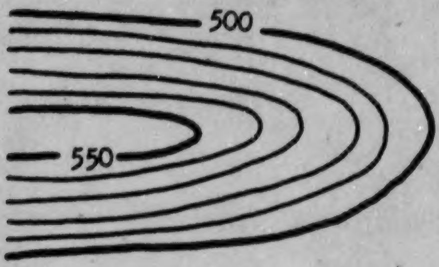
6. Contours cross streams in a "V" shaped manner pointing upstream.



7. Contours form an "M" above stream junctions.



8. Contours form a "U" around ridges, and the closed end of the "U" points down ridge.



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SELF TEST #1

If you are uncertain about a question or cannot answer it, refer back to the frame(s) indicated in parenthesis.

1. Elevation refers to the _________ of a _________ above or below mean sea level, and relief refers to _______________________________. (#1)

2. A contour line is a ______ on a map that represents an imaginary line on the surface of the ___________ along which all points lie at the _____ ___________. (#2)

3. The starting point from which elevation is measured is mean _____ __________ (#2)

4. Contour lines possess certain characteristics. They tend to __________ each other and __________ streams. They never __________ or fork. They tend to form __________ __________ curves and always close on themselves.

5. When we think of contour lines in relation to ridges, streams, and stream junctions, we think of the letters _____, _____, and _____. (#5)

789

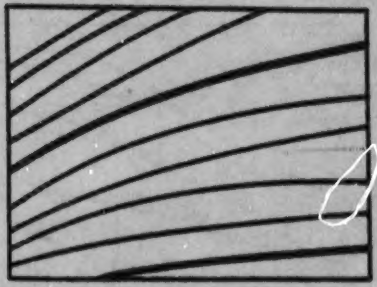
758

FRAME #6

There are two basic types of contour lines. INDEX contours are the first.

Index contours, the "key" type, are:
1. shown in a heavy line weight,
2. broken to allow insertion of elevation values, and
3. found every fifth (5th) line.

RE: The "key" type of contour line is the ______ contour. It is easily noticed because it is a ________ line weight and is ________ to allow insertion of elevations.



RE: This is a typical map sheet. The heavy lines are the Index contours. What is missing here? ______________________

790

ANS: Index, heavy, broken
Broken index contours, elevation values

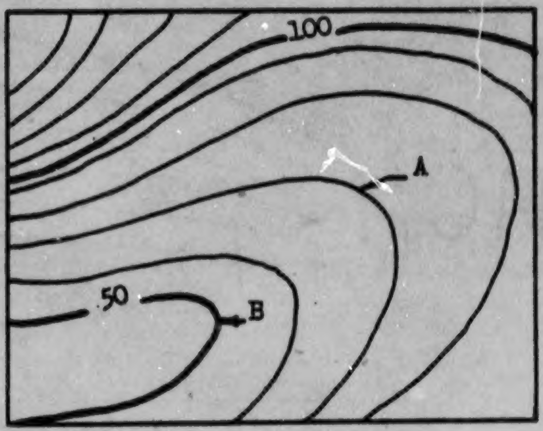
FRAME #7

Intermediate contours are the second type and are:

1. shown in a light line weight and

2. seldom broken.

RE: Intermediate contours can be distinguished from Index contours by their _______ line weight and the fact that they are ________ __________.



RE: Which (A or B) is the intermediate contour? ___

NOTE: There is one remaining type of contour line. It is called a supplementary contour. It occurs as a light series of dashes and is useful where the index and intermediate contours do not show the elevation and relief as accurately as may be needed.

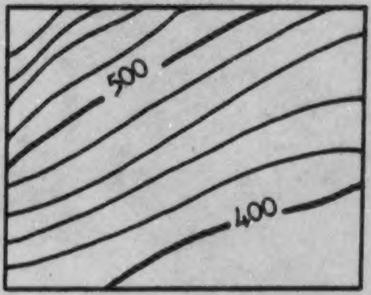
ANS: "A"

FRAME #8

On any contour map we refer to the vertical distance between contour lines as the contour interval. The contour interval is usually given in whole even numbers such as 20, 50, 100, or 500'.

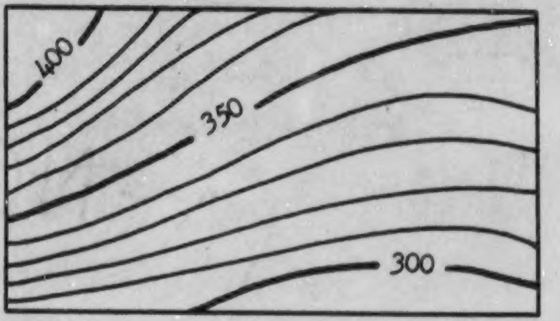
RE: The contour interval is the _________ distance between contour lines. It is usually found expressed as a ______ _________ number.

EXAMPLE



Contour Interval 20'

RE: The contour interval on the map sheet below is how many feet? ____

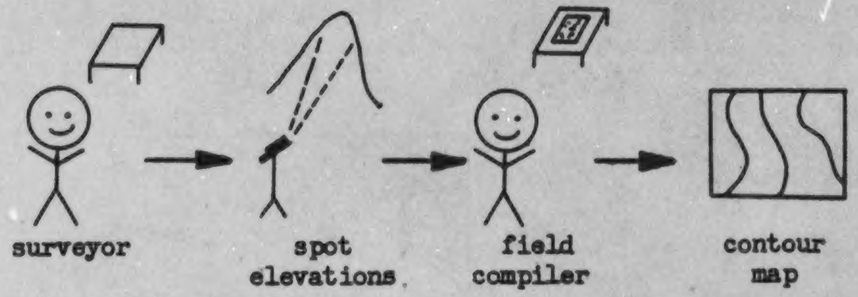


ANS: Contour Interval is 10'.

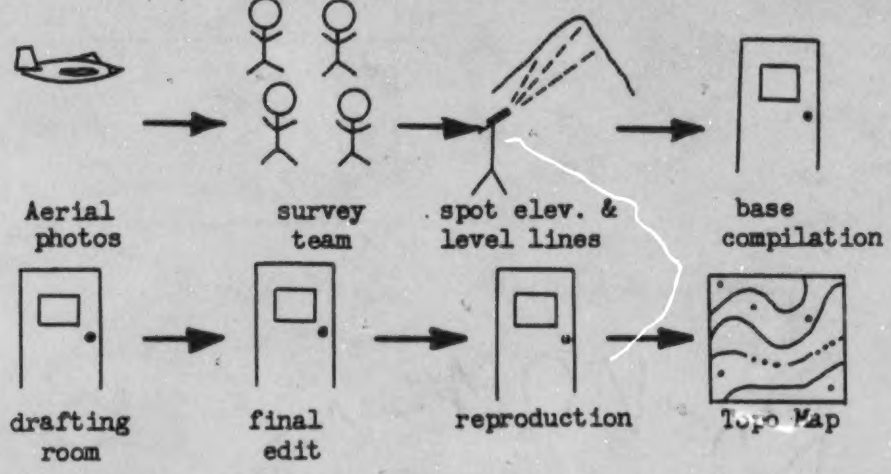
FRAME #9

Compilation of a contour map normally requires a gread deal of time (weeks or months). In field situations where speed is the important factor, logical contouring can be used with relatively little sacrifice of accuracy.

A.


surveyor
spot elevations
field compiler
contour map

B.


Aerial photos
survey team
spot elev. & level lines
base compilation
drafting room
final edit
reproduction
Topo Map

RE. Which (A or B) best depicts field compilation of a map?

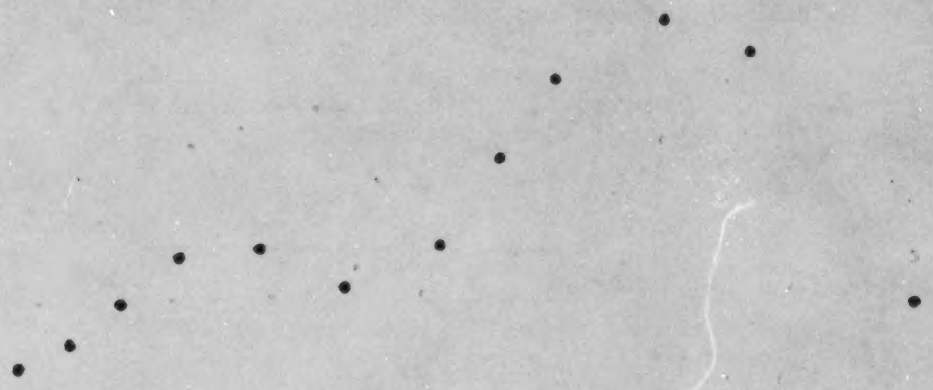
____

ANS: "A"

FRAME #10

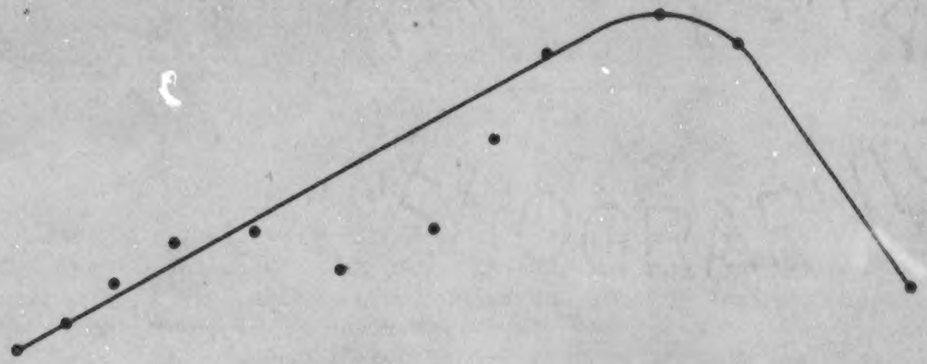
Logical contouring is based on the assumption that all slopes are uniform (the ground rises and falls evenly). This disregards some of natures irregularities. Logical contouring depends more on what the slope would be if there were only even changes between two or more points.

RE: The process of logical contouring is based on the assumption that all slopes are _______. This disregards some of natures _________.



Draw a line connecting these points indicating the type of slope assumed in logical contouring.

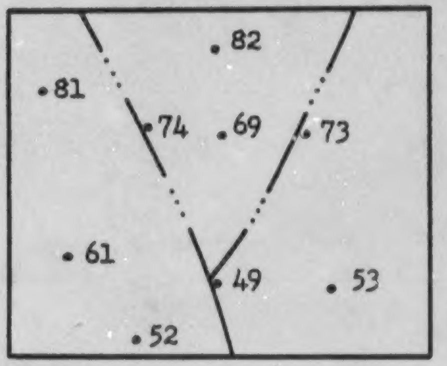
ANS: uniform, irregularities



FRAME #11

Logical contouring permits sketching of contours from field notes.* We can rely on the assumption of uniform slopes if the survey team furnishes us with a spot elevation at each point where there is a significant change in slope such as the crest of a hill or a stream bed.

* From field notes, existing maps, aerial photos, city or town property sheets, or from knowledge gained from area residents.



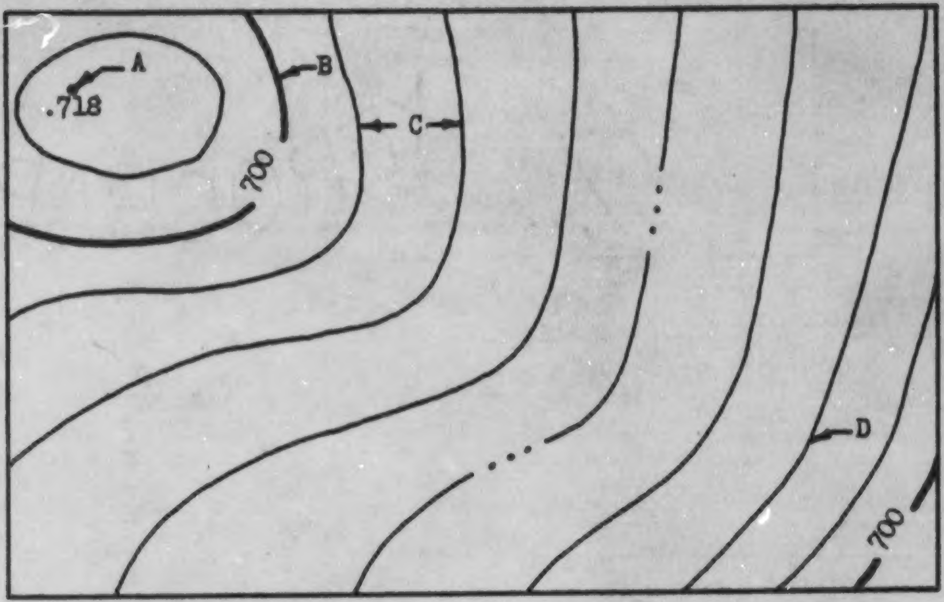
Surveyors Plane Table Sheet

RE: For the concept of uniform slopes to be valid, the survey team must provide us with a ____ ________ wherever a ________ of ________ occurs.

ANS: spot elevation, change, slope

SELF TEST #2

Name each of the features shown on the sheet. If you are uncertain about a feature, refer back to the frame indicated in parenthesis.



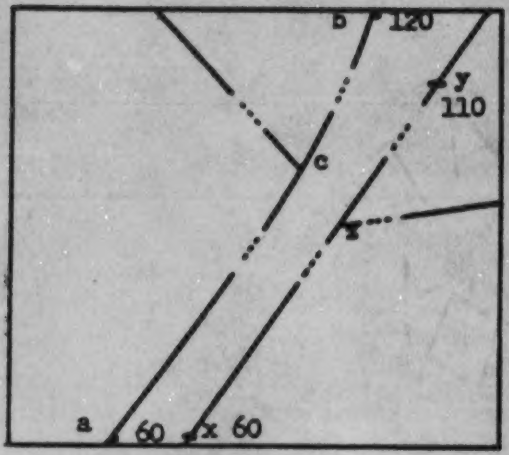
A. ________ ________ (#11) C. ________ ________ (#8)

B. ________ ________ (#6) D. ________ ________ (#7)

FRAME #12

There are 5 steps to follow in logical contouring.

STEP #1. Determine the elevation at all stream junctions.



READ CAREFULLY - WORK SLOWLY

With dividers or engineers scale, stream junction "c" was determined to be 2/3 the stream distance between points "a" and "b". The total difference in elevation is 60' (120-60). 2/3 of 60 = 40, so the elevation of "c" is said to be 60 + 40 or 100 feet.

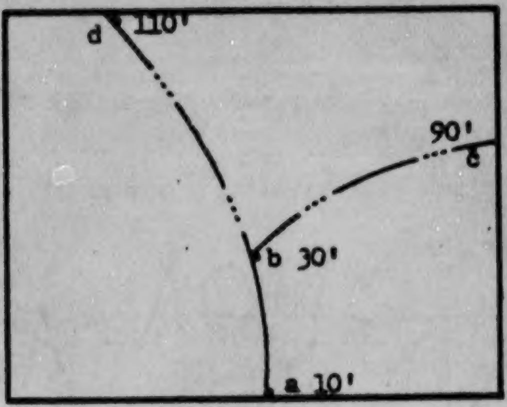
1. Determine the elevation at stream junction "z"
2. Plot the elevation at all stream junctions on your work sheet, page 22.

766

ANS: Approximately 90'

FRAME #13

STEP #2 Locate the points where the contours cross the streams. Remember to round out the point of the "V"s.



Contour Interval 20'

Points "a" and "b" are given. The contour interval is 20'. The 20' contour can be drawn ½ the distance between "a" and "b."

Look at stream b-d. The vertical distance is 80'. We can break the line into 8 equal parts of 10' each. The next break above point "b" will be at 40'. A contour line will cross here and at every other break (i.e. every 20').

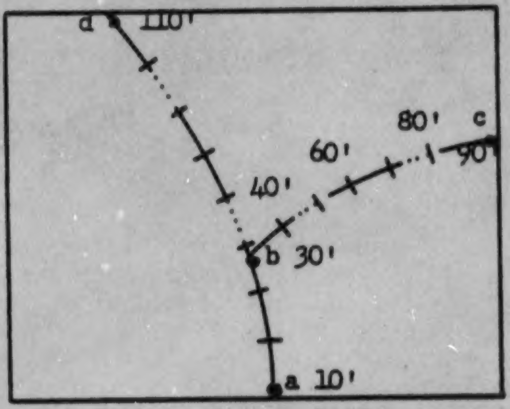
1. Locate the points where contours will cross the stream b-c.

2. On your work sheet, locate the points where contours will cross all the streams.

798

767

ANS:


d
110'
80'
c
60'
90'
40'
b
30'
a
10'

Contour Interval 20'

FRAME #14

STEP #3 Sketch in the ridge lines.

Streams are generally separated by areas of higher elevation (or a swamp or lake would be present). Ridge lines are sketched in by running a dashed line through the spot elevations (which indicate the crest of a ridge between the streams) starting at the stream junction and continuing through the last elevation given. See Figure 1.

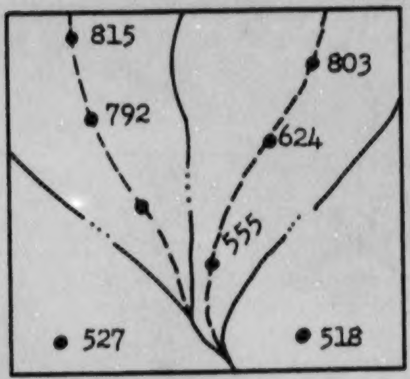

815
803
792
624
555
527
518

Fig. 1. Sample

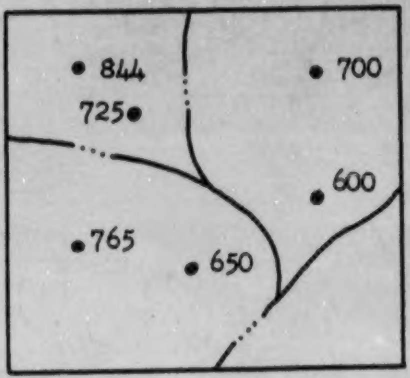
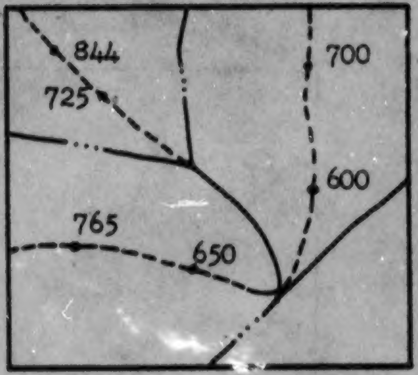

844
700
725
600
765
650

Fig. 2

1. In Figure 2, above, sketch in the ridge lines.
2. Sketch in all the ridge lines on your work sheet.

799

ANS:



FRAME #15

STEP #4 Locate the points where the contours cross the ridge lines.

This step is accomplished in the same manner as Step 2 prescribes. In Figure 1 the vertical difference between spot elevations is 60'. Divide the line into 6 equal parts (10' each). A contour line will go through each spot elevation and through each of the breaks in the line between them.

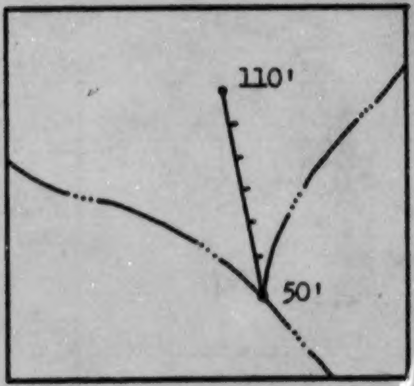


Fig. 1. Contour Int. 10'

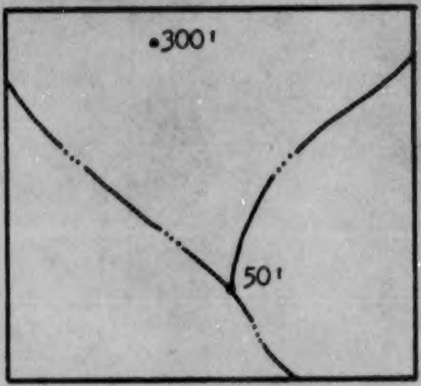


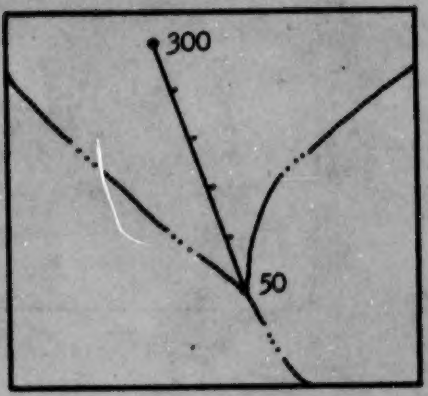
Fig. 2. Contour Int. 50'

1. In Figure 2, draw a ridge line between the spot elevations, and show where each contour would cross this line.

2. Following the above procedure, locate the points where contours cross the ridge lines you sketched in on your work sheet.

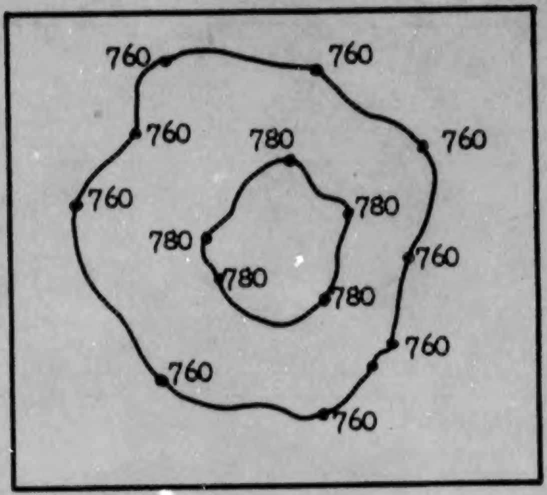
769

ANS:



FRAME # 16

STEP #5 Draw contours by connecting points of equal elevation.


760
760
760
780
760
760
780
780
760
780
780
760
760
760

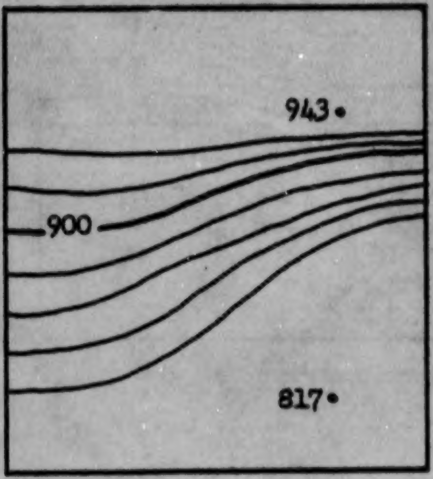
This sounds like a very easy step. It is. But don't be satisfied with this alone. See how frame 18 and 19 help you to understand this step.

801

FRAME # 17

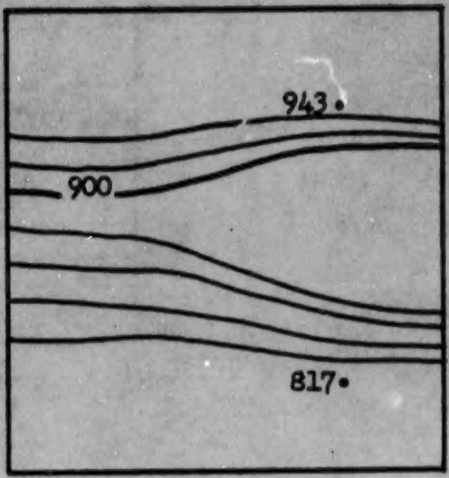
Figures 1 and 2 show you what an inexperienced compiler would do. Of course you would not do this since you know this violates the assumption of "uniform slopes." Frame #19 will show you the right way to draw in the contour lines.

Fig. 1



NO!

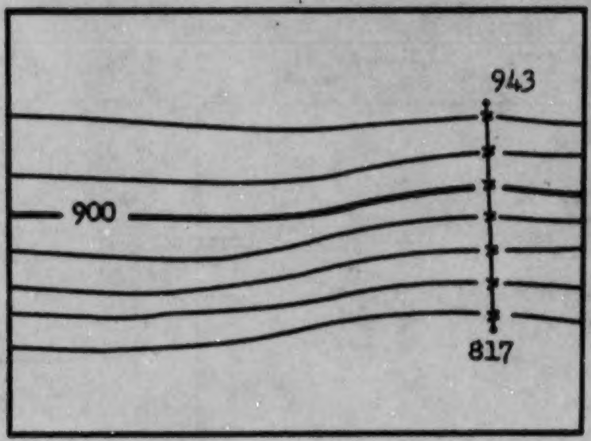
Fig. 2



NO!

FRAME #18

Look at the figure below. You would connect the 943' and 817' spot elevations with a line. Determine how many contours will be drawn between these spot elevations. Then divide the line so that the contours passing between these spot elevations will be evenly spaced.



Contour Interval 20'

Do this on your worksheet, between all spot elevations where contour lines will be drawn.

FRAME #19

When connecting points of equal elevation on a plane table sheet, you will find there is only one way a contour line can go. In Figure 1, there is only one place you can draw the 405' contour once it has reached point "X", and that is between the 404 and 407' points.

Figure 1

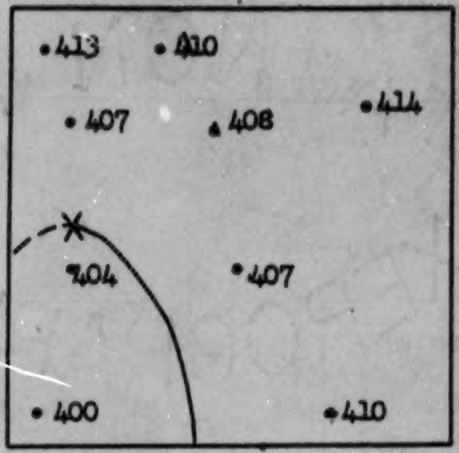
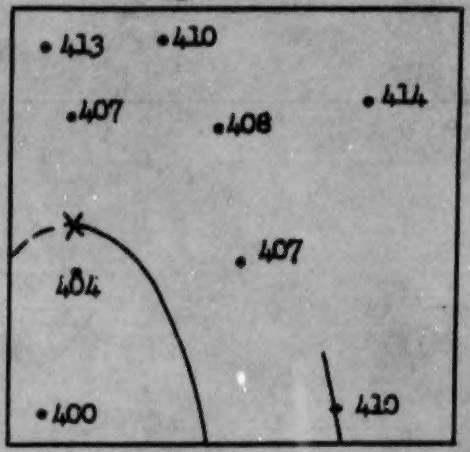

413
410
407
408
414
X
404
407
400
410

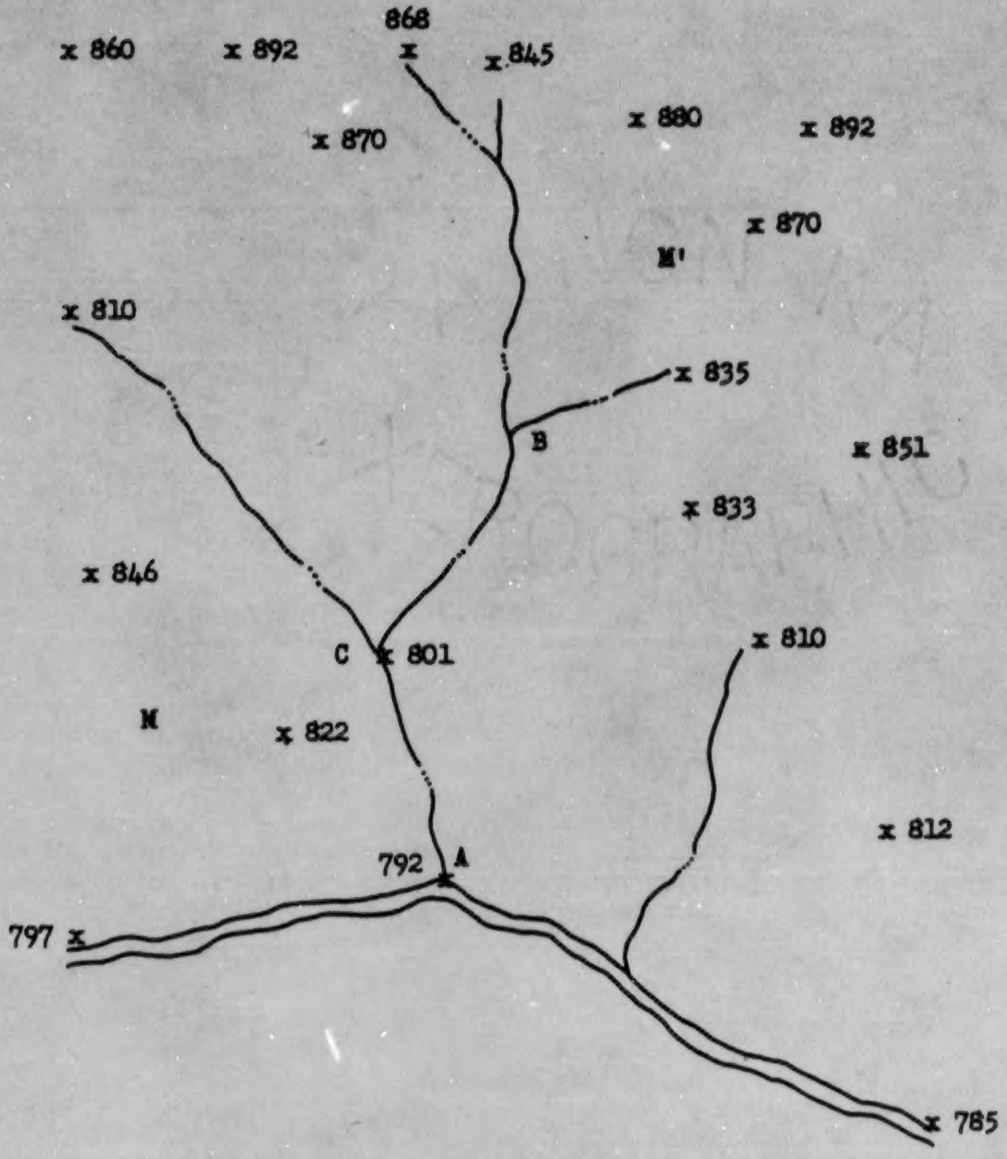
Figure 2


413
410
407
408
414
X
404
407
400
410

1. In Figure 2, can you finish drawing the 410' contour that we have already started for you?

2. You are now ready to complete your worksheet. Draw in all the contours (index and intermediate). When you have finished, erase all guidelines and have the instructor check your work.

WORK SHEET


x 860
x 892
868
x
x 845
x 870
x 880
x 892
x 870
M'
x 810
x 835
B
x 851
x 833
x 846
C
x 801
x 810
M
x 822
x 812
792
A
797 x
x 785

Contour Interval-10 Feet

774

PRACTICAL EXERCISE

SUBJECT: Map Compilation and Revision

LESSON: Logical Contouring

TIME: 1 Hour

MATERIALS AND EQUIPMENT:

4H Pencil
Practical Exercise Sheet
Dividers and/or Engineers Scale

METHOD: You will work individually at your own tables. Instructors will be present to assist you and check your work.

PROCEDURE: You are required to connect the points of equal elevation keeping in mind the principles and methods set forth in the lesson. When you have completed the sheet, hand it to the instructor.

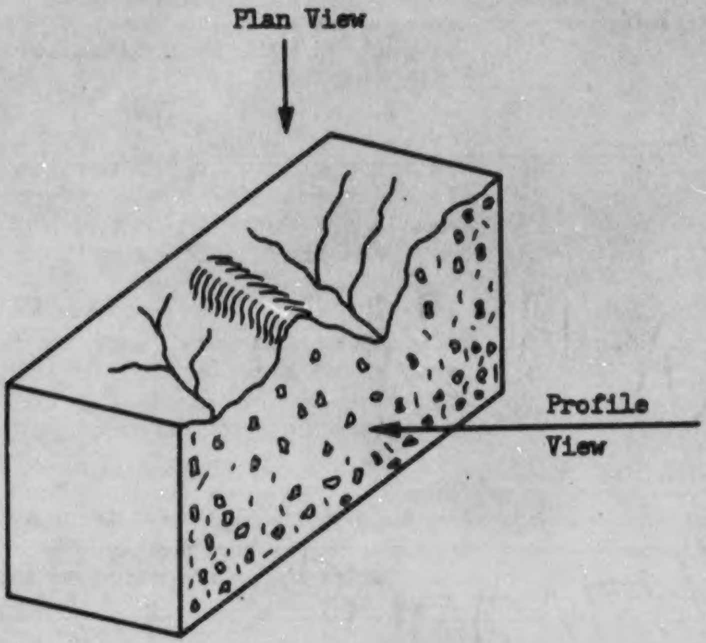
EVALUATION: Accuracy of ALL work, line weight, neatness, and form, as well as the application of the eight (8) characteristics of contours, will be checked in the evaluation and grading.

CRITIQUE: A critique will be held following the PE to correct mistakes and allow for suggestions in areas thought to need improvement.

PROFILES

FRAME #1

A profile is a side view of a portion of the earth along a line between two points.

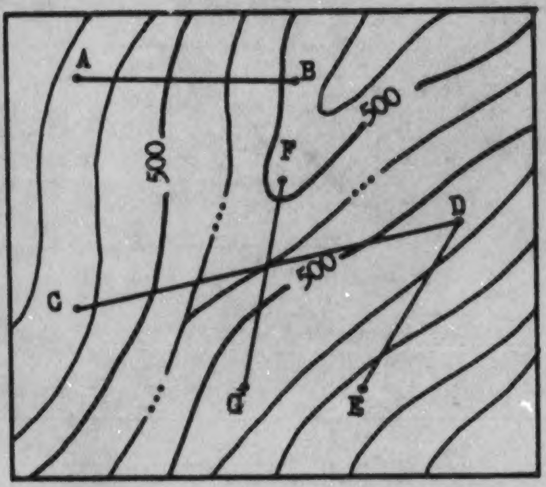

Plan View
Profile View

RE: A vertical aerial photo is not a profile view.
This is because it is not a __________ view.

ANS: Side

FRAME #2

A profile can be constructed from any contour map. A profile can only be constructed along a straight line. If we desire to show the profile of a curved road or stream, we must use a series of profiles each of which is constructed along a straight line.



Any of these straight lines (AB, CD, DE, FG) is a line along which a profile can be constructed.

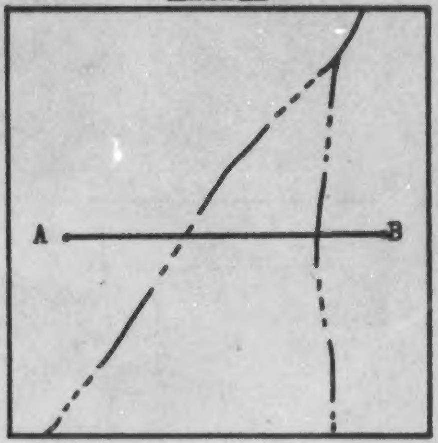
777

FRAME #3

There are 6 simple steps to follow when constructing a profile.

STEP #1 Draw a line along the area you wish to profile.

EXAMPLE

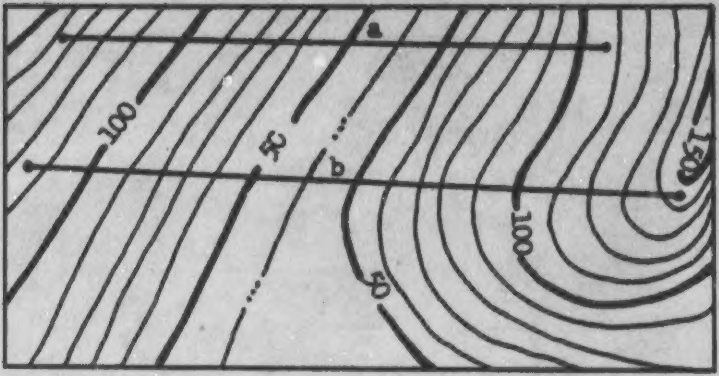


Do this between points M and M' on the worksheet, page 22.

809

FRAME #4

STEP #2 Make a note of the highest and lowest contours (in terms of feet) that your profile line crosses.



1. The highest contour line that line "a" above crosses has a value of 130', and the lowest line it crosses has a value of 50'.

2. The highest contour that line "b" crosses is at ____' and the lowest contour line it crosses is at _____'.

3. Determine these values for line MM' on your worksheet.

779

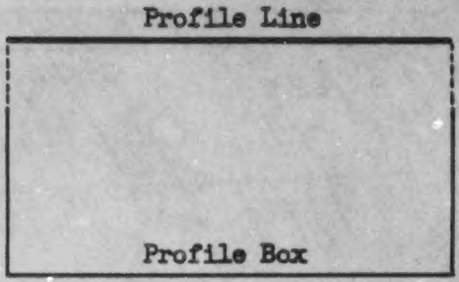
ANS: 140' is the highest contour and 50' is the lowest contour.

FRAME #5

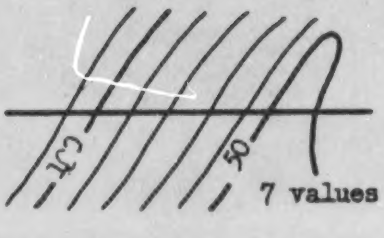
NOTE: Complete each portion of Step #3 on your worksheet.

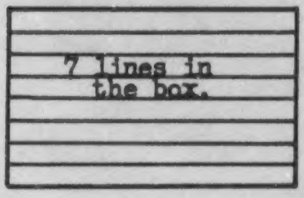
Step #3

a) Construct a box within which your profile will be drawn. The box will be as wide as your profile line is long. Do this on a clean sheet of paper.


Profile Line
Profile Box

b) There will be a horizontal line in the box for each contour value the profile line crosses. Space the lines evenly.....just remember, the wider the spacing the greater the vertical exaggeration.

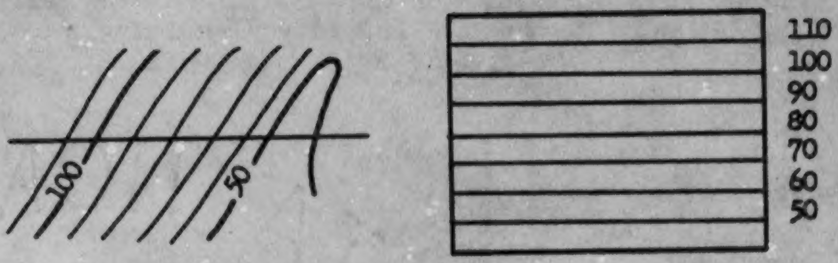



7 lines in the box.

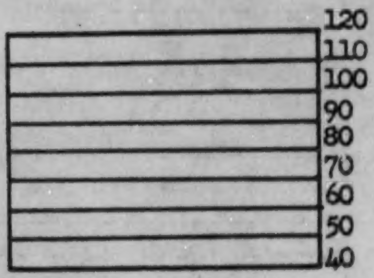
FRAME #6

Step #4

a) Assign a contour value to each line in the box.


100
50
110
100
90
80
70
60
50

b) Number the top and bottom line of the box with the next highest and lowest contour value.

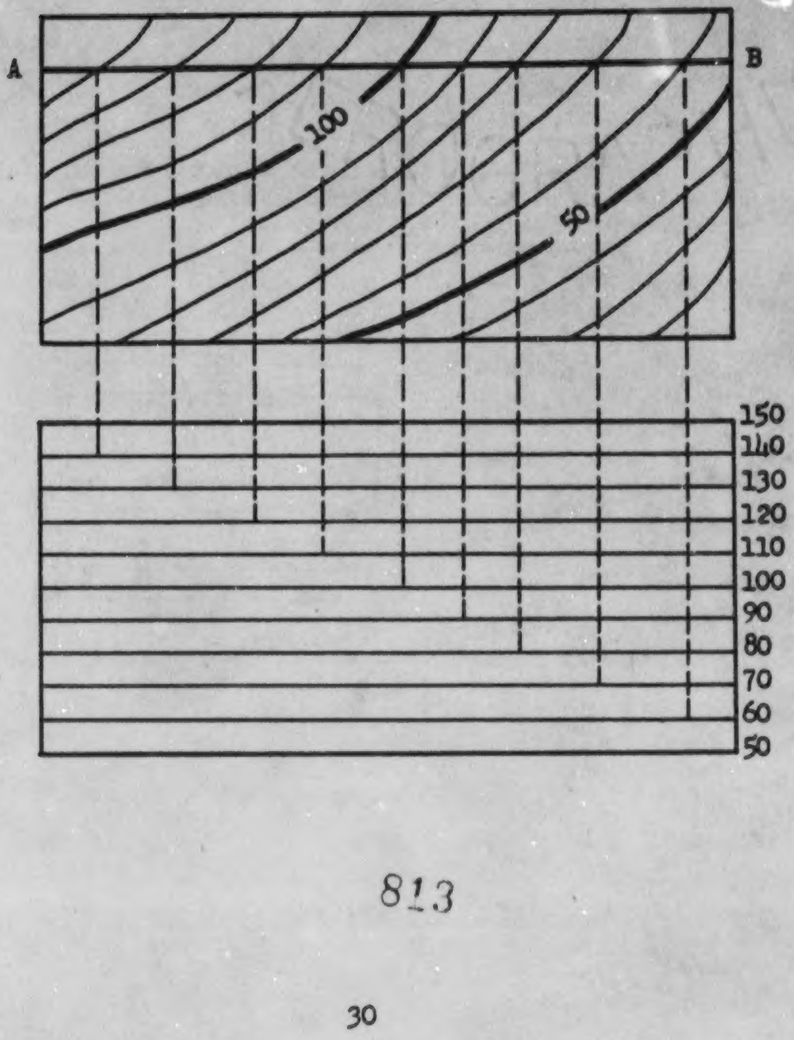

120
110
100
90
80
70
60
50
40

This will give you room to round out the hills and valleys.

781

FRAME #7

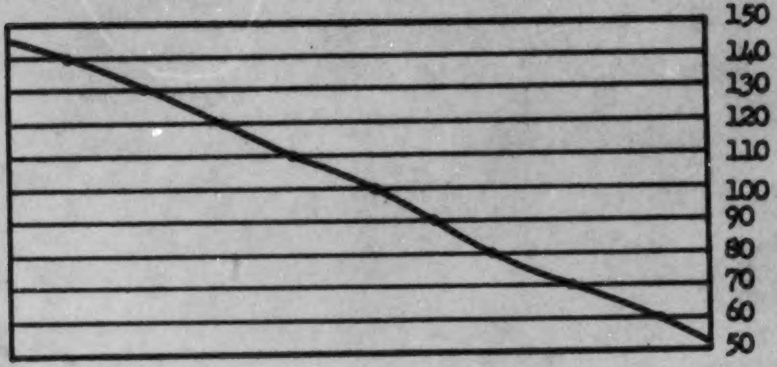
STEP #5 Drop perpendiculars from the intersection of each contour line with the profile line to the line of corresponding value in your profile box.


A
B
100
50
150
140
130
120
110
100
90
80
70
60
50

813

FRAME #8

STEP #6 Draw the profile by connecting the points with a smooth natural curve.



Complete your profile for line M-M'. When you have finished, have the instructor check your work.

411-200-C-010-070

PROGRAMMED LESSON

LOGICAL CONTOURING

DEPARTMENT OF DEFENSE

MARCH 1975

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

784

TO THE STUDENT

This programmed lesson is essentially a workbook. The lesson information is broken into small sequential units called frames, which enable you to make an active response.

Study each frame carefully and complete each response. The correct response will be found on the page following each frame. There is no answer sheet. Do not proceed to the next frame until you have mastered all the information in the present frame. An instructor will assist you if the need arises.

This booklet is your property. Do all your work in the spaces provided. This is not a test. However, the Practical Exercise will be collected and evaluated to determine how well you have met the objectives. The self-tests are designed to summarize units of instruction and provide a means whereby you can measure how well you are learning the information. You may work at your own pace. Begin with Frame #1 on page 1.

816

STATEMENT OF OBJECTIVES

The purpose of this lesson is to provide you with the knowledge and ability required to prepare contour maps in the field using the logical contouring procedure. This lesson is designed to enable you to:

A. DEFINE A CONTOUR

1. Recognize the difference between elevation and relief.
2. List the characteristics of contour lines (8).
3. Define the types of contour lines.
4. Define contour interval.

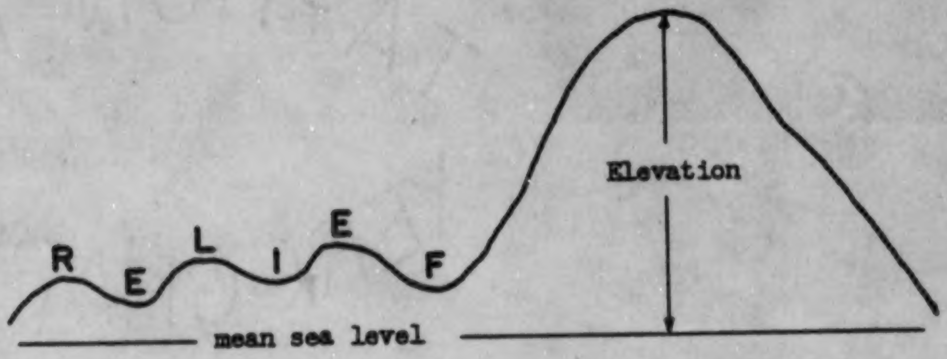
B. SKETCH CONTOURS ON A PLANE TABLE SHEET

1. Determine elevations at stream junctions.
2. Determine where contours cross streams and sketch in the contours.
3. Determine and sketch in ridge line locations.
4. Determine where contours cross ridge lines and sketch in the contours.

FRAME #1

In any type of mapping it is essential to understand the difference between elevation and relief.

The distinction is a simple one. Elevation refers to the height of a point above or below mean sea level, while relief refers to the general shape of the ground.



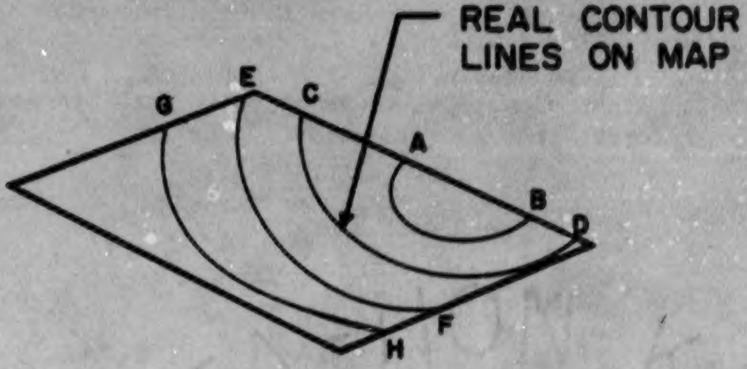
RE: The height of a point above or below mean sea level is its __________. The shape of the ground is its ____________________.

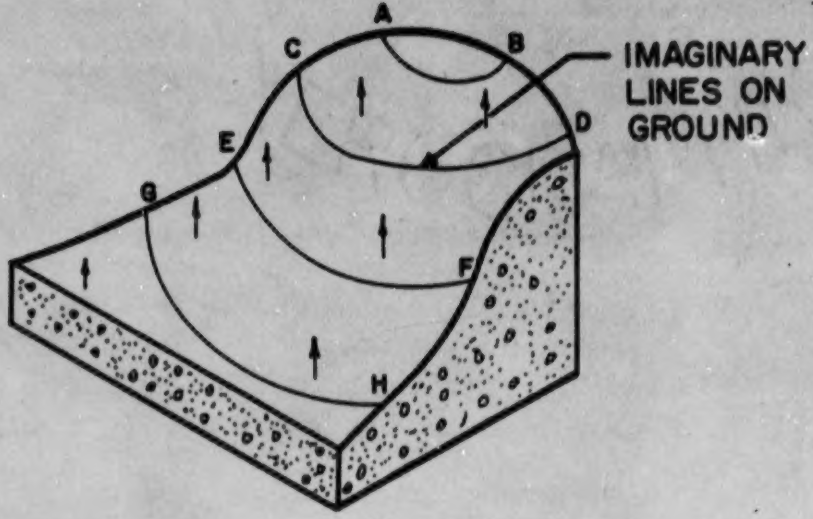
Do elevations show relief? __________

ANS: Elevation, relief, yes

FRAME #2

A contour line is a line on a map that represents an imaginary line on the surface of the earth along which all points lie at the same elevation. Mean sea level is the starting point or "O" elevation.


REAL CONTOUR LINES ON MAP
G
E
C
A
B
D
F
H


A
C
B
IMAGINARY LINES ON GROUND
D
E
G
F
H

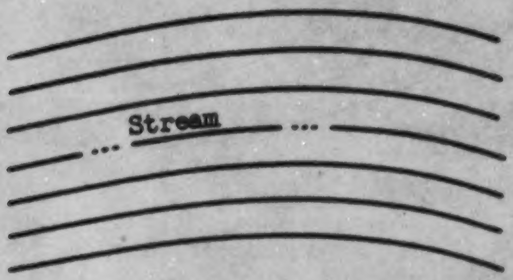
RE: Any line connecting a series of points of equal elevation can properly be called a __________ line.

ANS: Contour

FRAME #3

Contour lines possess eight (8) fundamental characteristics. The first three of these are:

1. Contours tend to parallel each other and tend to parallel streams, or man made features such as railroads.

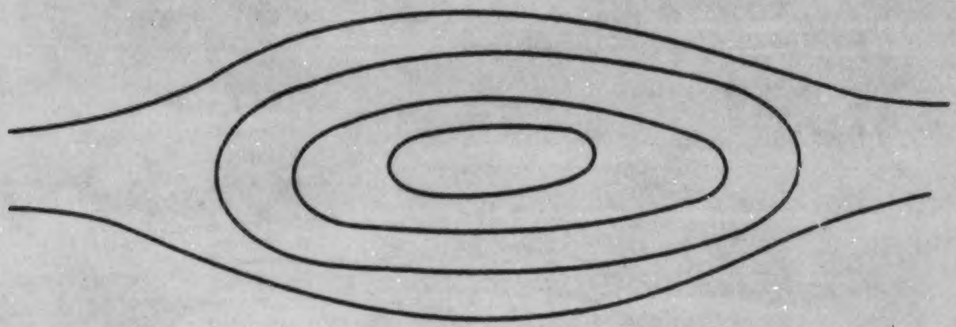


2. Contours never cross or touch except at overhanging or vertical cliffs and at waterfalls.
3. Contours never fork.

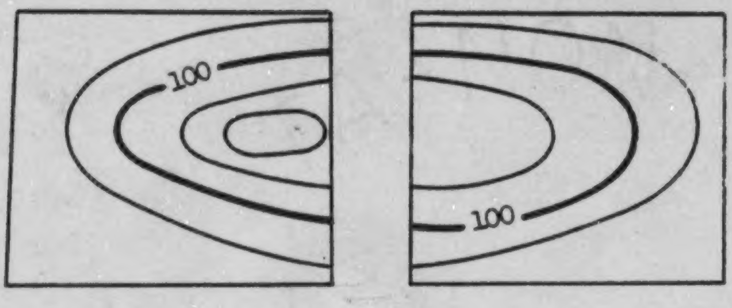
FRAME #4

Characteristics 4 and 5 are:

4. Contours form smooth natural curves.



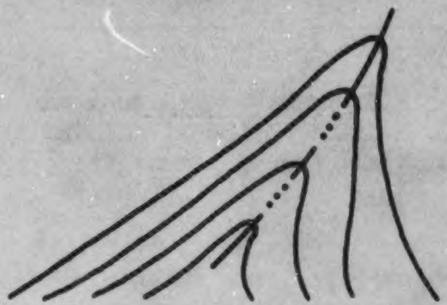
5. Contours always close on themselves either inside or outside the limits of your map sheet.



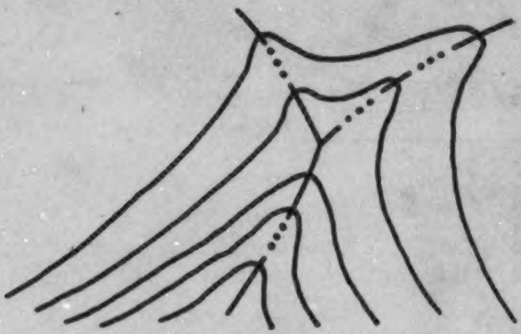
FRAME #5

The remaining three characteristics are:

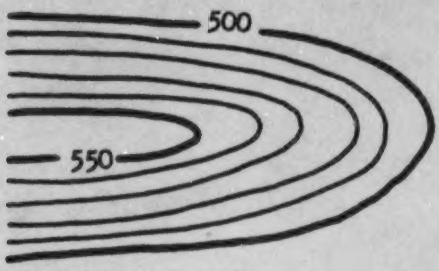
6. Contours cross streams in a "V" shaped manner pointing upstream.



7. Contours form an "M" above stream junctions.



8. Contours form a "U" around ridges, and the closed end of the "U" points down ridge.



SELF TEST #1

If you are uncertain about a question or cannot answer it, refer back to the frame(s) indicated in parenthesis.

1. Elevation refers to the _________ of a _________ above or below mean sea level, and relief refers to ______________________________ (#1)

2. A contour line is a ______ on a map that represents an imaginary line on the surface of the ___________ along which all points lie at the _____ ___________. (#2)

3. The starting point from which elevation is measured is mean _____ _________ (#2)

4. Contour lines possess certain characteristics. They tend to _________ each other and _________ streams. They never _________ or fork. They tend to form _________ _________ curves and always close on themselves.

5. When we think of contour lines in relation to ridges, streams, and stream junctions, we think of the letters _____, _____, and _____. (#5)

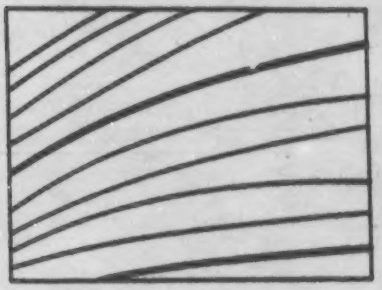
FRAME #6

There are two basic types of contour lines. INDEX contours are the first.

Index contours, the "key" type, are:

1. shown in a heavy line weight,
2. broken to allow insertion of elevation values, and
3. found every fifth (5th) line.

RE: The "key" type of contour line is the _______ contour. It is easily noticed because it is a _________ line weight and is _________ to allow insertion of elevations.



RE: This is a typical map sheet. The heavy lines are the Index contours. What is missing here? ____________________________

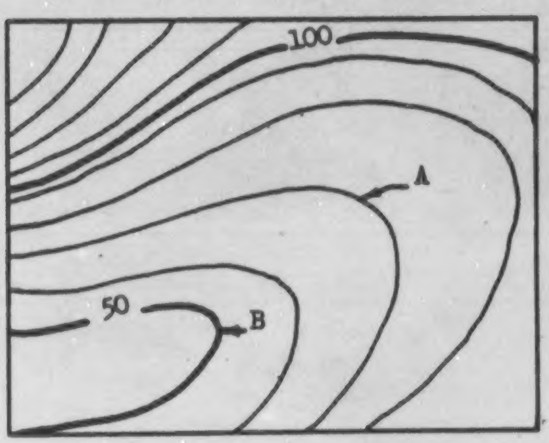
ANS: Index, heavy, broken
Broken index contours, elevation values

FRAME #7

Intermediate contours are the second type and are:

1. shown in a light line weight and
2. seldom broken.

RE: Intermediate contours can be distinguished from Index contours by their _______ line weight and the fact that they are ________ __________.



RE: Which (A or B) is the intermediate contour? ____

NOTE: There is one remaining type of contour line. It is called a supplementary contour. It occurs as a light series of dashes and is useful where the index and intermediate contours do not show the elevation and relief as accurately as may be needed.

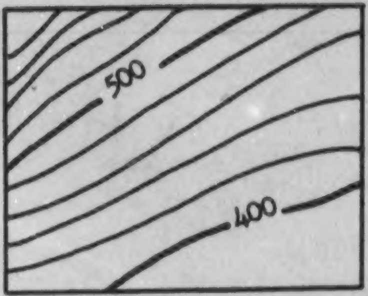
ANS: "A"

FRAME #8

On any contour map we refer to the vertical distance between contour lines as the contour interval. The contour interval is usually given in whole even numbers such as 20, 50, 100, or 500'.

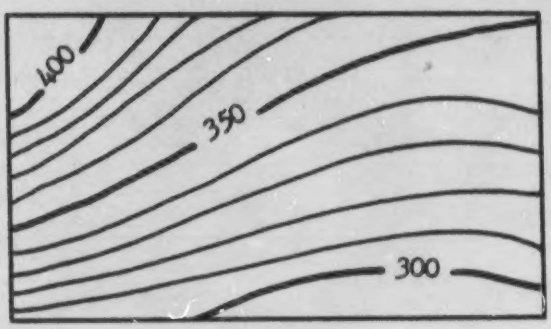
RE: The contour interval is the ________ distance between contour lines. It is usually found expressed as a ______ ________ number.

EXAMPLE



Contour Interval 20'

RE: The contour interval on the map sheet below is how many feet? ____

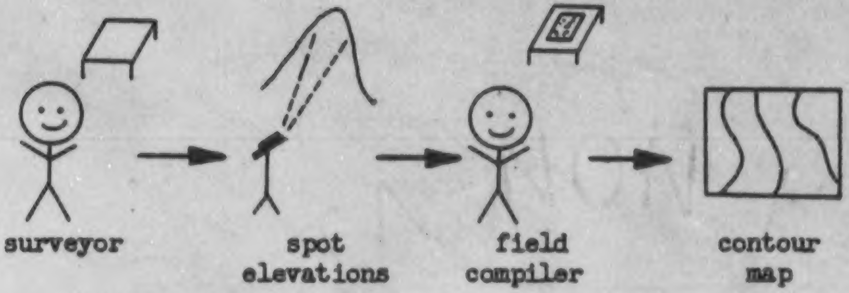


ANS: Contour Interval is 10'.

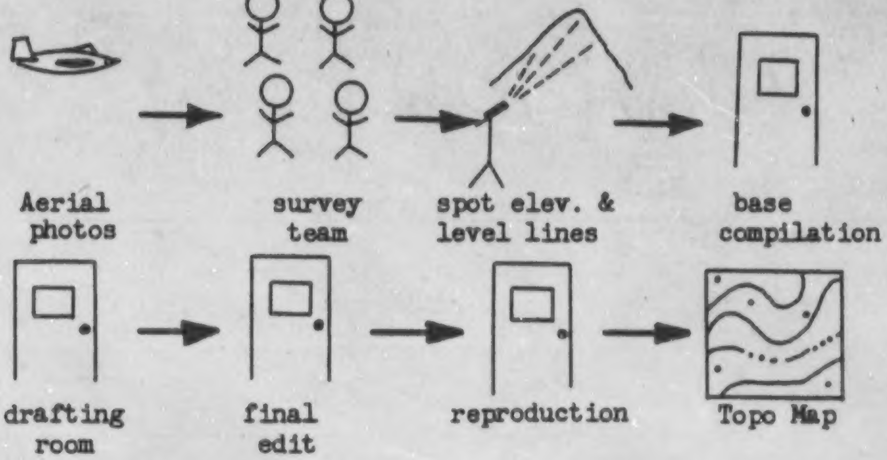
FRAME #9

Compilation of a contour map normally requires a gread deal of time (weeks or months). In field situations where speed is the important factor, logical contouring can be used with relatively little sacrifice of accuracy.

A.


surveyor
spot elevations
field compiler
contour map

B.


Aerial photos
survey team
spot elev. & level lines
base compilation
drafting room
final edit
reproduction
Topo Map

RE. Which (A or B) best depicts field compilation of a map?

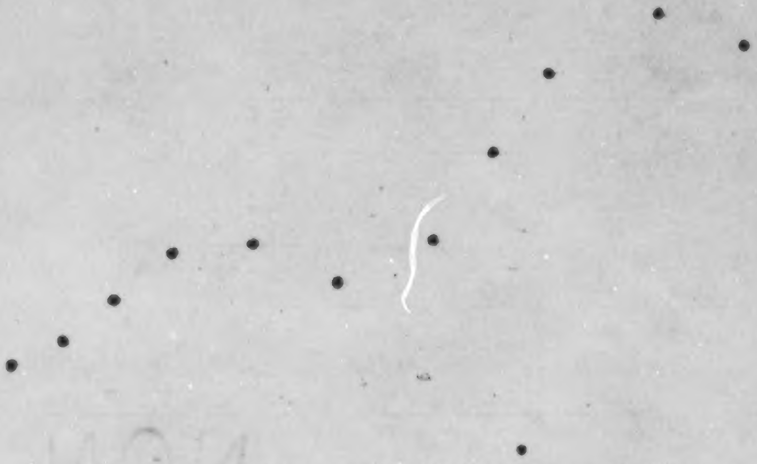
____

ANS: "A"

FRAME #10

Logical contouring is based on the assumption that all slopes are uniform (the ground rises and falls evenly). This disregards some of natures irregularities. Logical contouring depends more on what the slope would be if there were only even changes between two or more points.

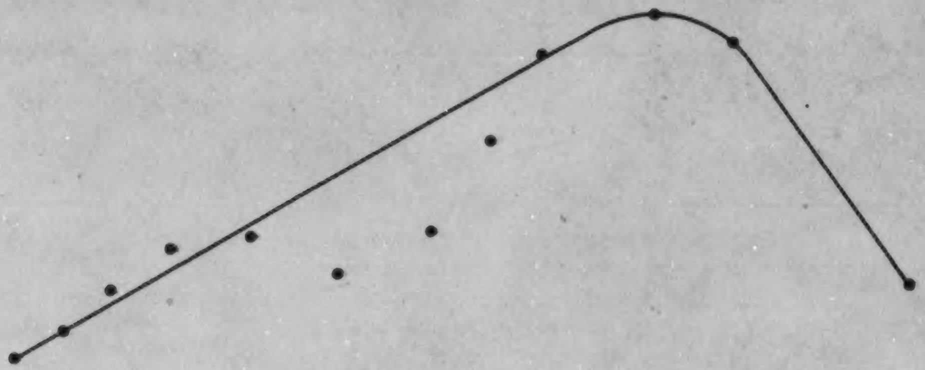
RE: The process of logical contouring is based on the assumption that all slopes are ______. This disregards some of natures ________.



Draw a line connecting these points indicating the type of slope assumed in logical contouring.

797

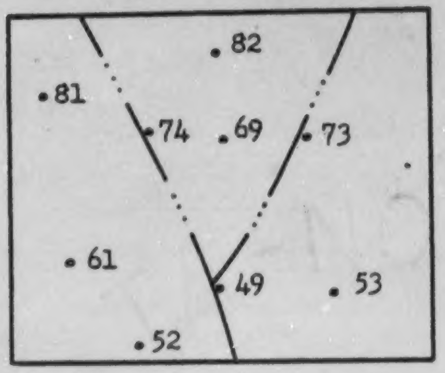
ANS: uniform, irregularities



FRAME #11

Logical contouring permits sketching of contours from field notes.* We can rely on the assumption of uniform slopes if the survey team furnishes us with a spot elevation at each point where there is a significant change in slope such as the crest of a hill or a stream bed.

* From field notes, existing maps, aerial photos, city or town property sheets, or from knowledge gained from area residents.



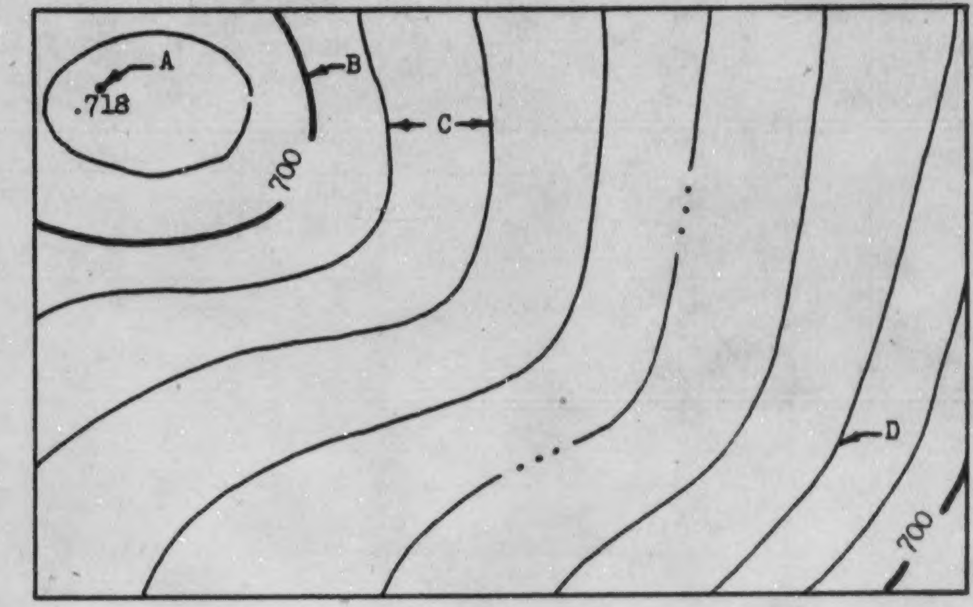
Surveyors Plane Table Sheet

RE: For the concept of uniform slopes to be valid, the survey team must provide us with a _____ _________ wherever a _________ of _________ occurs.

ANS: spot elevation, change, slope

SELF TEST #2

Name each of the features shown on the sheet. If you are uncertain about a feature, refer back to the frame indicated in parenthesis.



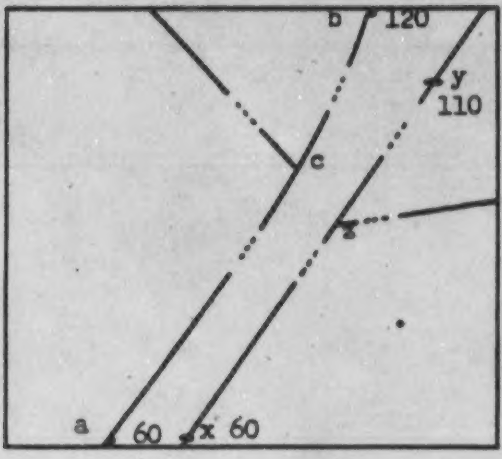
A. ______ ________ (#11) C. ______ ________ (#8)

B. ______ ________ (#6) D. ______ ________ (#7)

FRAME #12

There are 5 steps to follow in logical contouring.

STEP #1. Determine the elevation at all stream junctions.



READ CAREFULLY - WORK SLOWLY

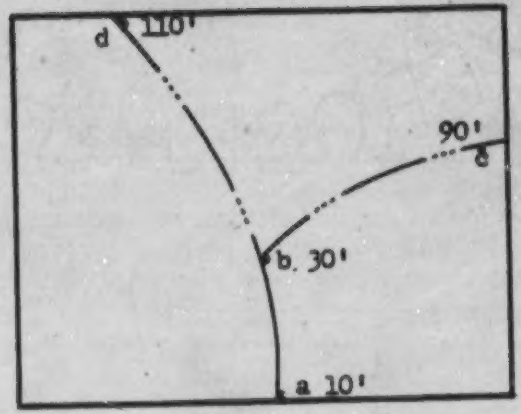
With dividers or engineers scale, stream junction "c" was determined to be 2/3 the stream distance between points "a" and "b". The total difference in elevation is 60' (120-60). 2/3 of 60 = 40, so the elevation of "c" is said to be 60 + 40 or 100 feet.

1. Determine the elevation at stream junction "z"
2. Plot the elevation at all stream junctions on your work sheet, page 22.

ANS: Approximately 90'

FRAME # 13

STEP #2 Locate the points where the contours cross the streams. Remember to round out the point of the "V"s.



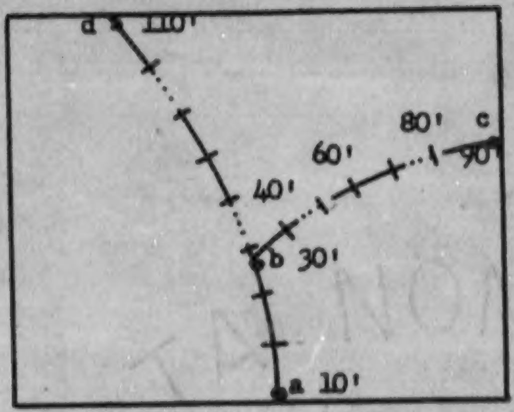
Contour Interval 20'

Points "a" and "b" are given. The contour interval is 20'. The 20' contour can be drawn ½ the distance between "a" and "b."

Look at stream b-d. The vertical distance is 80'. We can break the line into 8 equal parts of 10' each. The next break above point "b" will be at 40'. A contour line will cross here and at every other break (i.e. every 20').

1. Locate the points where contours will cross the stream b-c.
2. On your work sheet, locate the points where contours will cross all the streams.

ANS:


d
110'
80'
c
60'
90'
40'
b
30'
a
10'

Contour Interval 20'

FRAME #14

STEP #3 Sketch in the ridge lines.

Streams are generally separated by areas of higher elevation (or a swamp or lake would be present). Ridge lines are sketched in by running a dashed line through the spot elevations (which indicate the crest of a ridge between the streams) starting at the stream junction and continuing through the last elevation given. See Figure 1.

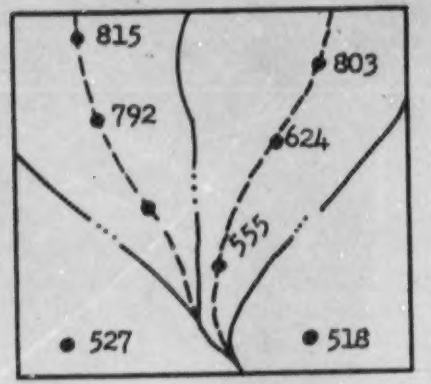

815
803
792
624
555
527
518

Fig. 1. Sample

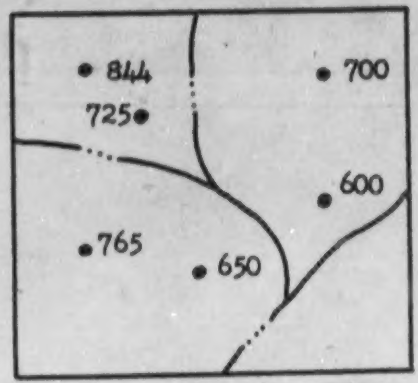
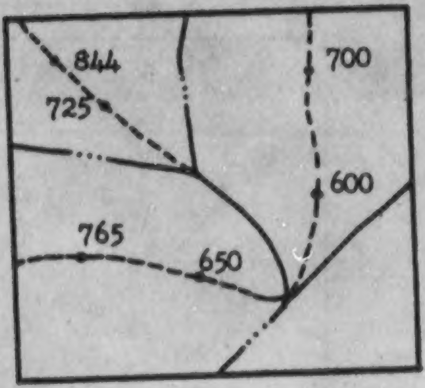

844
700
725
600
765
650

Fig. 2

1. In Figure 2, above, sketch in the ridge lines.
2. Sketch in all the ridge lines on your work sheet.

ANS:



FRAME #15

STEP #4 Locate the points where the contours cross the ridge lines.

This step is accomplished in the same manner as Step 2 prescribes. In Figure 1 the vertical difference between spot elevations is 60'. Divide the line into 6 equal parts (10' each). A contour line will go through each spot elevation and through each of the breaks in the line between them.

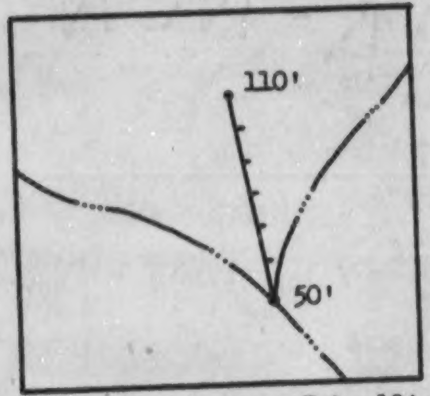


Fig. 1. Contour Int. 10'

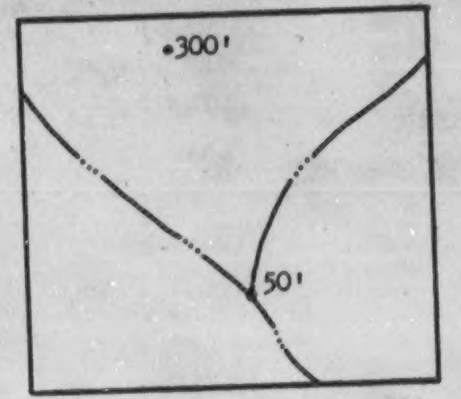
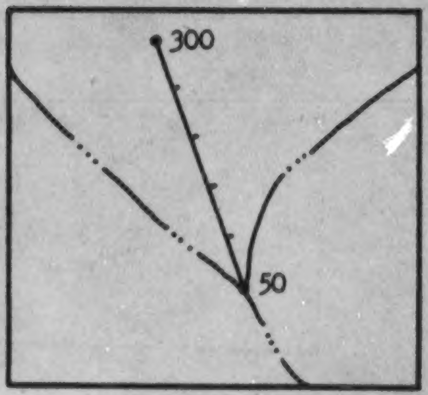


Fig. 2. Contour Int. 50'

1. In Figure 2, draw a ridge line between the spot elevations, and show where each contour would cross this line.
2. Following the above procedure, locate the points where contours cross the ridge lines you sketched in on your work sheet.

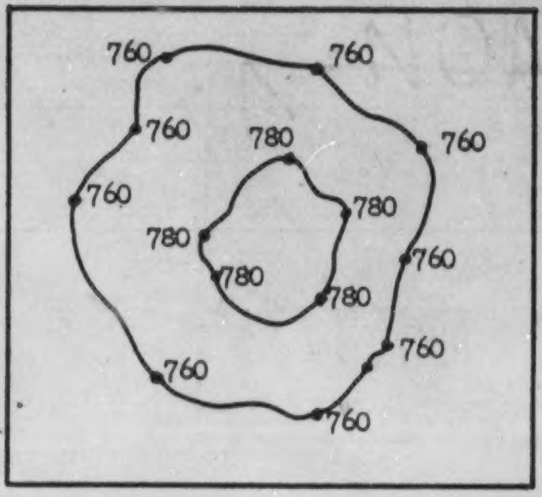
803

ANS:



FRAME # 16

STEP #5 Draw contours by connecting points of equal elevation.


760
760
760
760
760
780
780
780
780
780
780
760
760
760
760

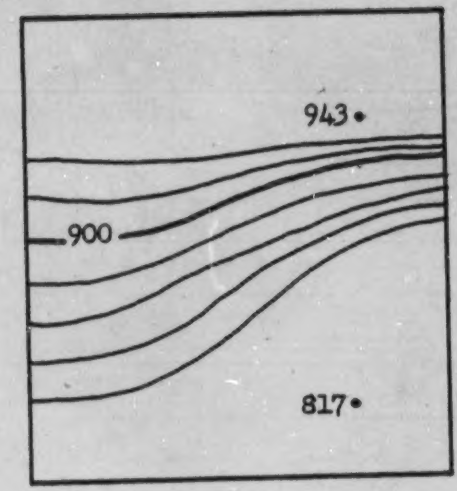
This sounds like a very easy step. It is. But don't be satisfied with this alone. See how frame 18 and 19 help you to understand this step.

835

FRAME # 17

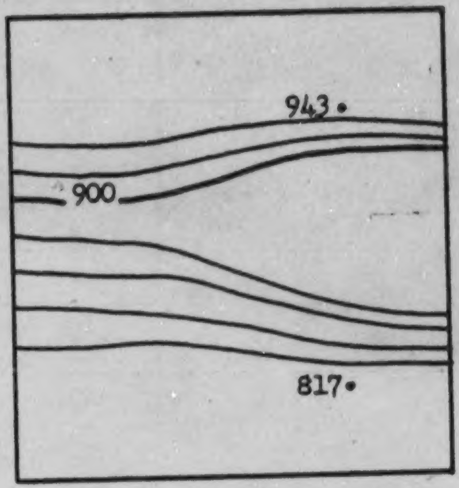
Figures 1 and 2 show you what an inexperienced compiler would do. Of course you would not do this since you know this violates the assumption of "uniform slopes." Frame #19 will show you the right way to draw in the contour lines.

Fig. 1



NO!

Fig. 2

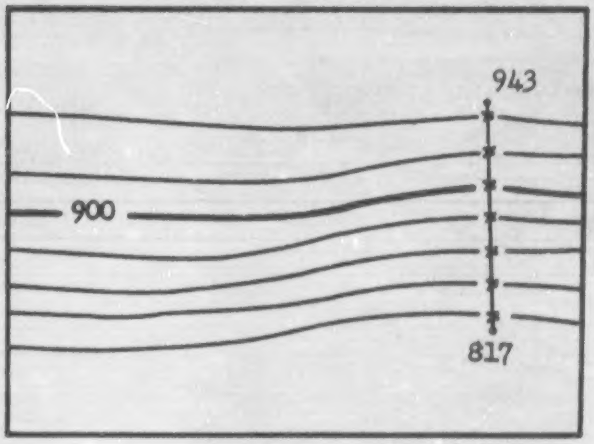


NO!

805

FRAME #18

Look at the figure below. You would connect the 943' and 817' spot elevations with a line. Determine how many contours will be drawn between these spot elevations. Then divide the line so that the contours passing between these spot elevations will be evenly spaced.



Contour Interval 20'

Do this on your worksheet, between all spot elevations where contour lines will be drawn.

837

FRAME #19

When connecting points of equal elevation on a plane table sheet, you will find there is only one way a contour line can go. In Figure 1, there is only one place you can draw the 405' contour once it has reached point "X", and that is between the 404 and 407' points.

Figure 1

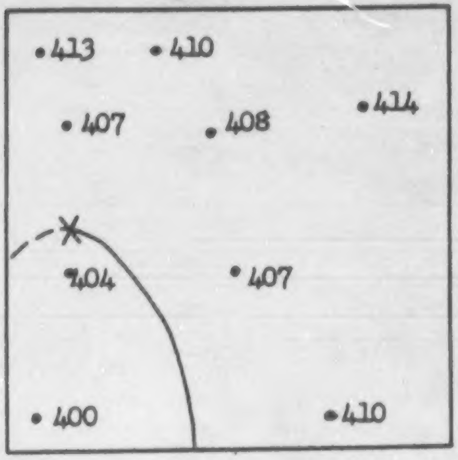
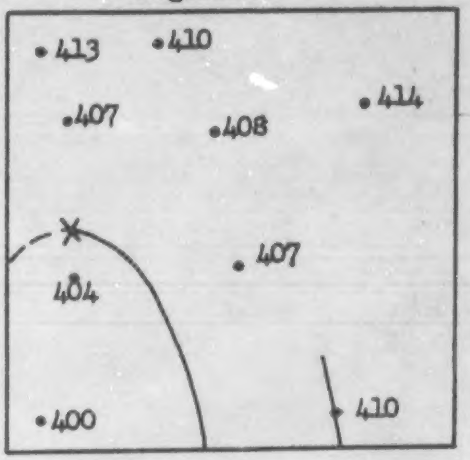

413
410
407
408
414
X
404
407
400
410

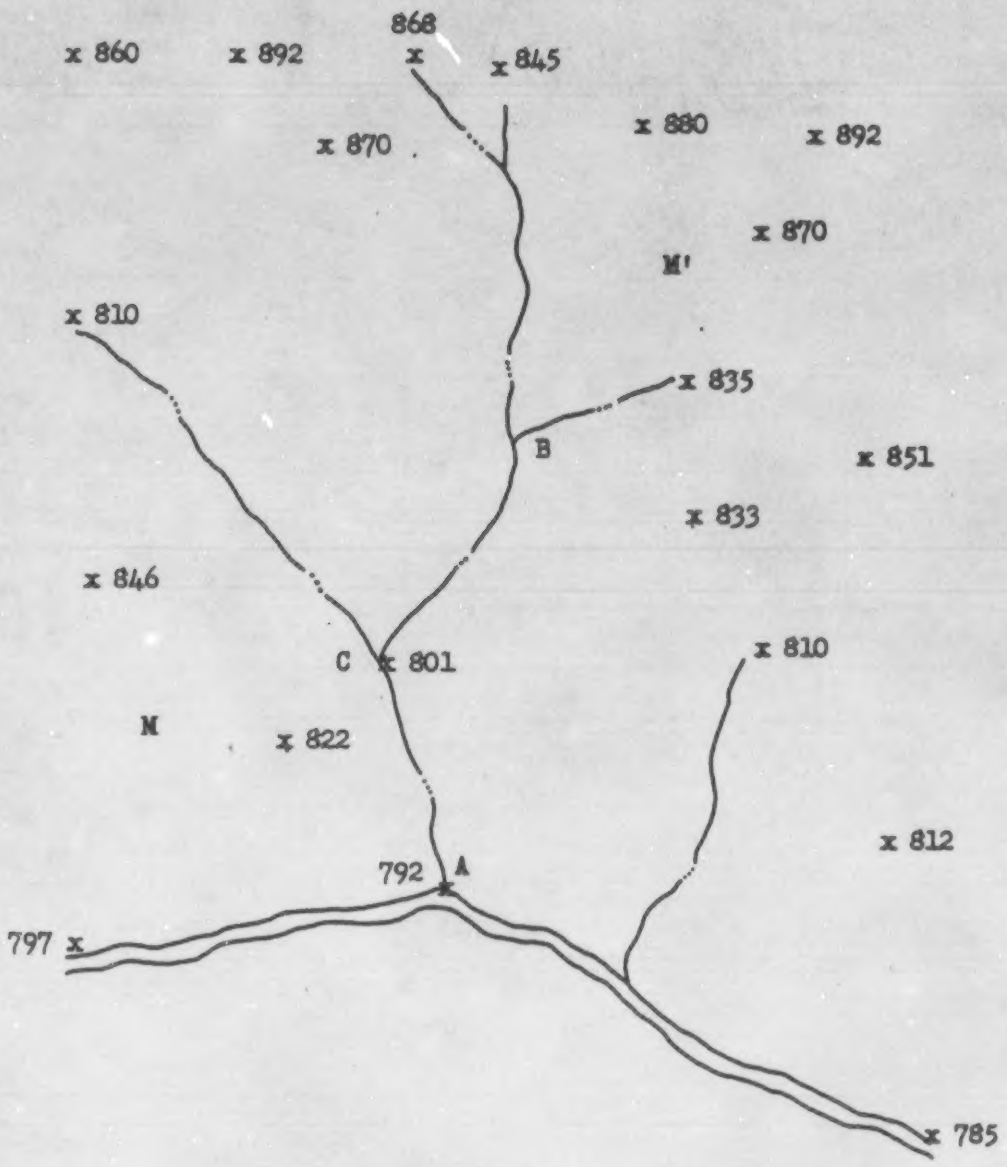
Figure 2


413
410
407
408
414
X
407
404
400
410

1. In Figure 2, can you finish drawing the 410' contour that we have already started for you?
2. You are now ready to complete your worksheet. Draw in all the contours (index and intermediate). When you have finished, erase all guidelines and have the instructor check your work.

807

WORK SHEET


x 860
x 892
868 x
x 845
x 870
x 880
x 892
x 870
M'
x 810
x 835
B
x 851
x 833
x 846
C
x 801
x 810
N
x 822
x 812
792
A
797 x
x 785

Contour Interval-10 Feet

PRACTICAL EXERCISE

MATERIALS AND EQUIPMENT:

4H Pencil
Practical Exercise Sheet
Dividers and/or Engineers Scale

METHOD: You will work individually at your own tables. Instructors will be present to assist you and check your work.

PROCEDURE: You are required to connect the points of equal elevation keeping in mind the principles and methods set forth in the lesson. When you have completed the sheet, hand it to the instructor.

EVALUATION: Accuracy of ALL work, line weight, neatness, and form, as well as the application of the eight (8) characteristics of contours, will be checked in the evaluation and grading.

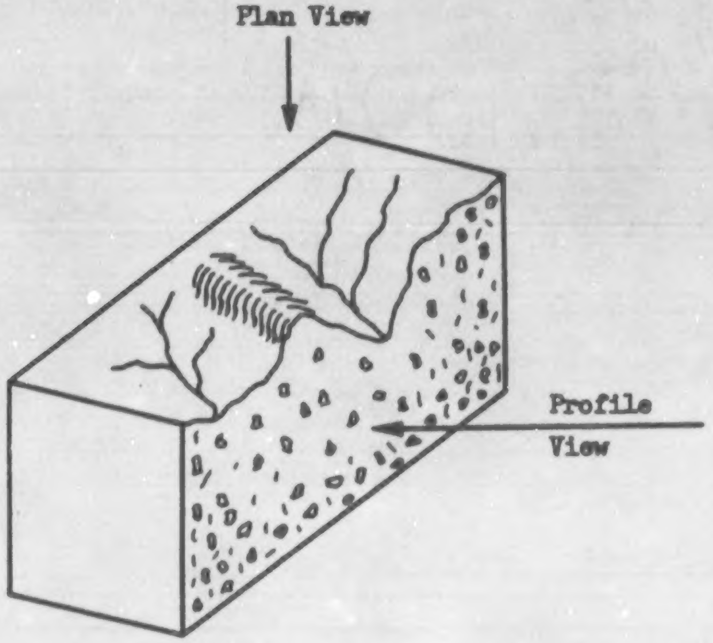
CRITIQUE: A critique will be held following the PE to correct mistakes and allow for suggestions in areas thought to need improvement.

809

PROFILES

FRAME #1

A profile is a side view of a portion of the earth along a line between two points.


Plan View
Profile View

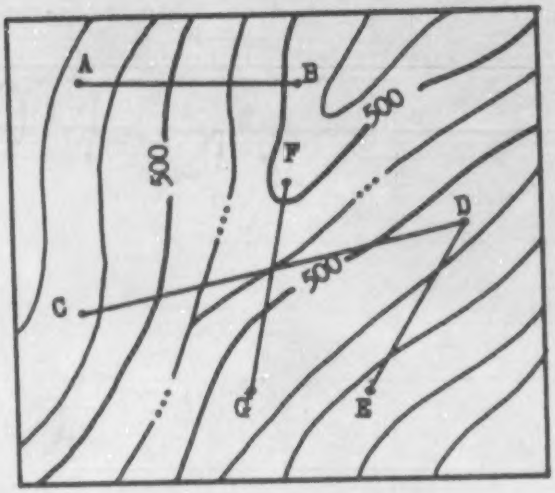
RE: A vertical aerial photo is not a profile view.
This is because it is not a __________ view.

841

ANS: Side

FRAME #2

A profile can be constructed from any contour map. A profile can only be constructed along a straight line. If we desire to show the profile of a curved road or stream, we must use a series of profiles each of which is constructed along a straight line.



Any of these straight lines (AB, CD, DE, FG) is a line along which a profile can be constructed.

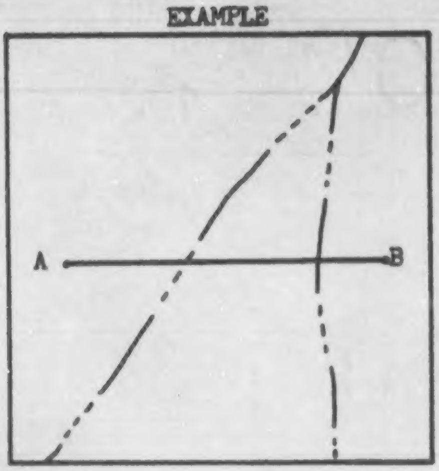
811

FRAME #3

There are 6 simple steps to follow when constructing a profile.

STEP #1 Draw a line along the area you wish to profile.

EXAMPLE



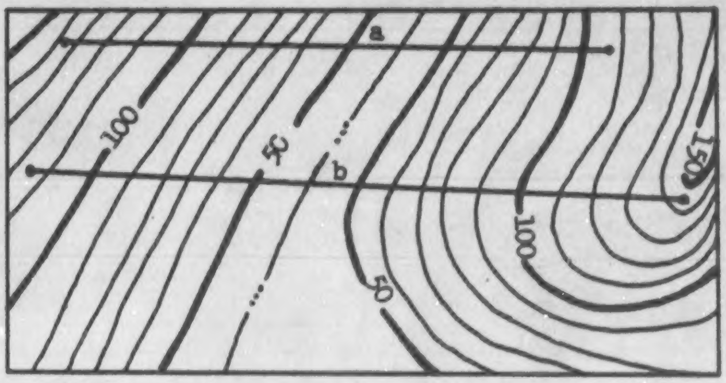
Do this between points M and M' on the work-sheet, page 22.

843

812

FRAME #4

STEP #2 Make a note of the highest and lowest contours (in terms of feet) that your profile line crosses.



1. The highest contour line that line "a" above crosses has a value of 130', and the lowest line it crosses has a value of 50'.

2. The highest contour that line "b" crosses is at ____' and the lowest contour line it crosses is at _____'.

3. Determine these values for line MM' on your worksheet.

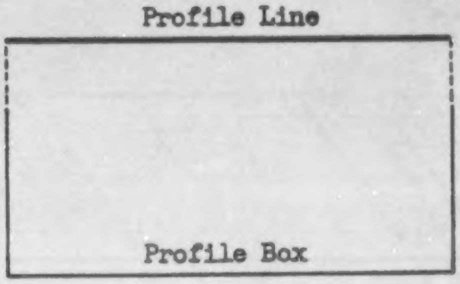
ANS: 140' is the highest contour and 50' is the lowest contour.

FRAME #5

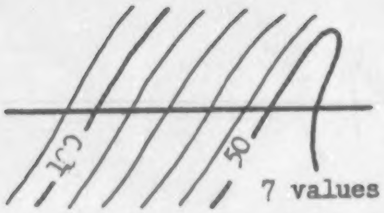
NOTE: Complete each portion of Step #3 on your worksheet.

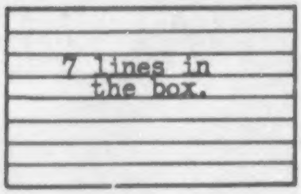
Step #3

a) Construct a box within which your profile will be drawn. The box will be as wide as your profile line is long. Do this on a clean sheet of paper.


Profile Line
Profile Box

b) There will be a horizontal line in the box for each contour value the profile line crosses. Space the lines evenly.....just remember, the wider the spacing the greater the vertical exaggeration.

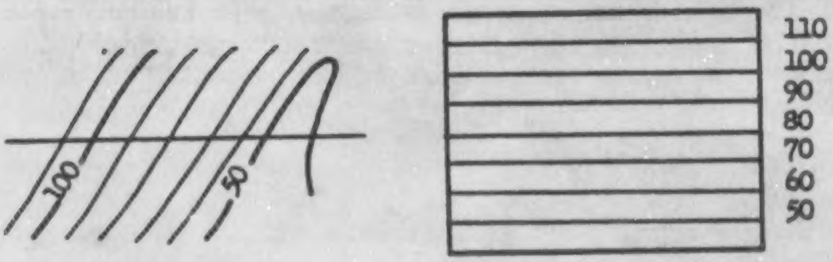

100
50
7 values


7 lines in the box.

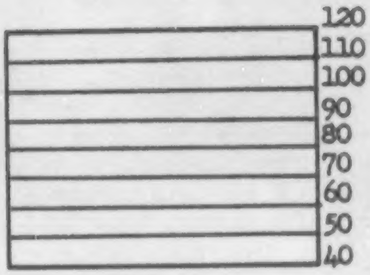
FRAME #6

Step #4

a) Assign a contour value to each line in the box.


100
50
110
100
90
80
70
60
50

b) Number the top and bottom line of the box with the next highest and lowest contour value.

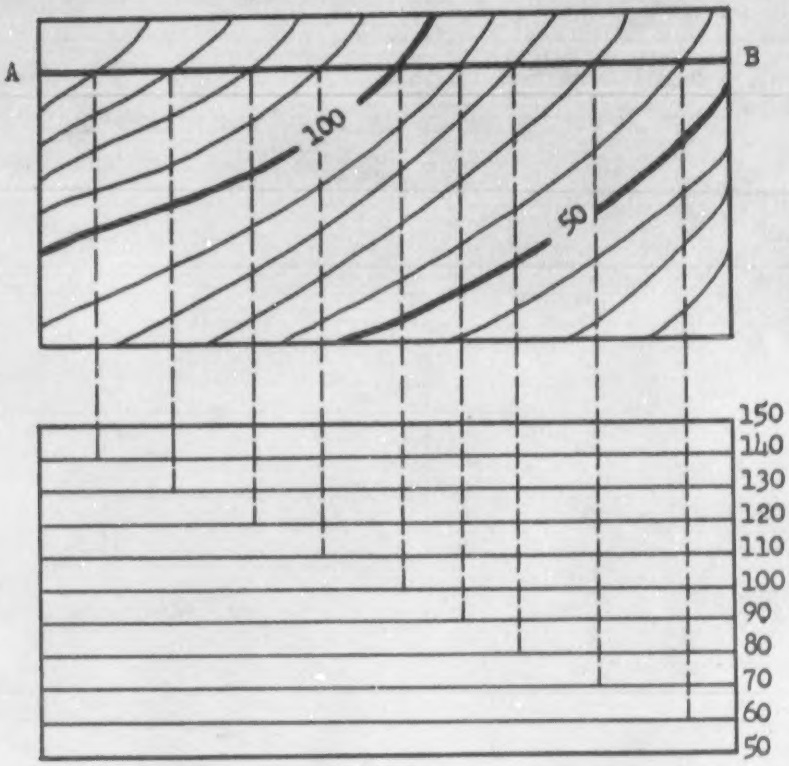

120
110
100
90
80
70
60
50
40

This will give you room to round out the hills and valleys.

815

FRAME #7

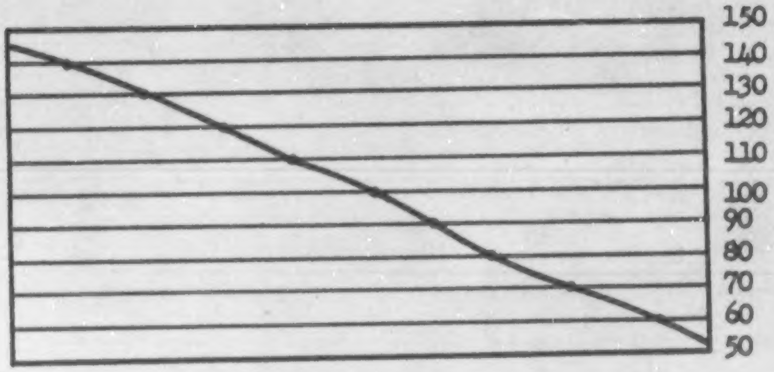
STEP #5 Drop perpendiculars from the intersection of each contour line with the profile line to the line of corresponding value in your profile box.


A
B
100
50
150
140
130
120
110
100
90
80
70
60
50

816

FRAME #8

STEP #6 Draw the profile by connecting the points with a smooth natural curve.



Complete your profile for line M-M'. When you have finished, have the instructor check your work.

818

[illegible]

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

INTRODUCTION

In your previous lesson, you were taught the field procedures, notekeeping, checking field notes for omissions, errors and blunders.

Up to this point, you have learned how the mean M values are determined. The next step is to resolve these mean readings into an Uncorrected Distance or (UD).

This task must be performed accurately and with care, as the further reduction to a Geodetic Length depends on the UD being 100% correct.

Upon completion of this Programed Text, you will be able to resolve the mean M values to derive an Uncorrected Distance.

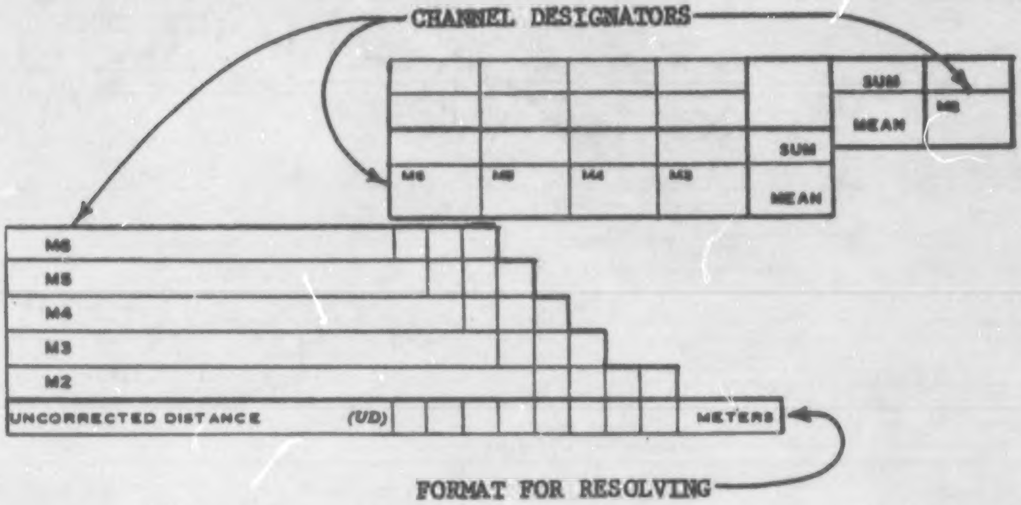
INSTRUCTIONS

There are two frames on each page of this text; however, since it is not desireable to put consecutive frames on the same page, you will have to turn the page after answering each question to check your answer and to continue with the program. In other words, Frame 2 appears at the top of page 5; the answer to Frame 2 is found in the top column on page 6; Frame 3 appears in the top column of page 7, etc. Follow the top frames all the way to page 23; the answer to Frame 11 on page 24 is found in the first column of page 24. Got it? OK, go to Frame 1.

FRAME 1

The figure below is the portion of DA Form 2857 that contains the raw data necessary for computation of uncorrected distance (UD) and the format for the computation.

Study it carefully to determine the relationship between the channel designators of the mean readings and the channel designators in the resolution format.


CHANNEL DESIGNATORS
SUM
MEAN
SUM
MEAN
M6
M5
M4
M3
M6
M5
M4
M3
M2
UNCORRECTED DISTANCE (UD)
METERS
FORMAT FOR RESOLVING

GO TO THE NEXT FRAME

FRAME 12

The situation you've been involved with to this point has been an ideal one. You may have noticed that each M value added a digit but also repeated the first two digits of the lesser M value. You will likely never see this occur in an actual field situation.

GO TO THE NEXT FRAME

Solution to Criterion Test

If your answer do not look like the solution shown below, you have misunderstood the information presented in this lesson. Raise your hand for additional help from the instructor.

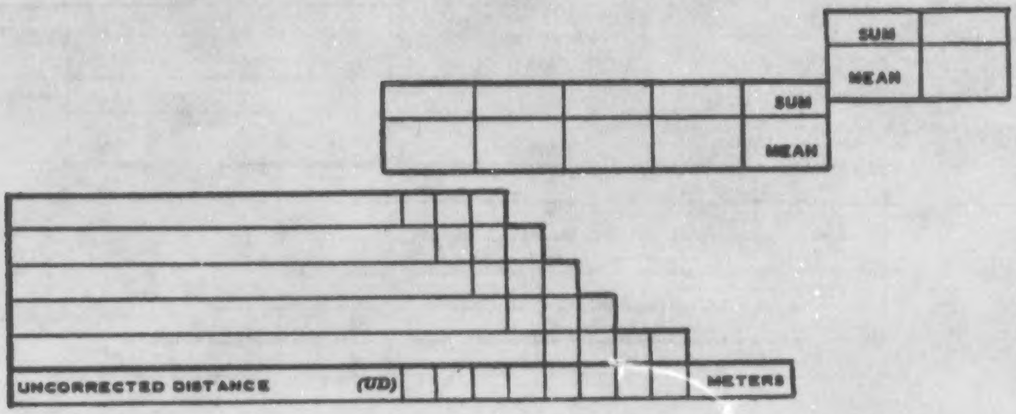
SUM	
MEAN	M2 2107

				SUM
M6 095	M5 662	M4 019	M3 456	MEAN

M6		0	9	5						
M5			6	6	2					
M4				0	1	9				
M3					4	5	6			
M2						2	1	0	7	
UNCORRECTED DISTANCE	(UD)	0	7	0	4	2	1	0	7	METERS

FRAME 2

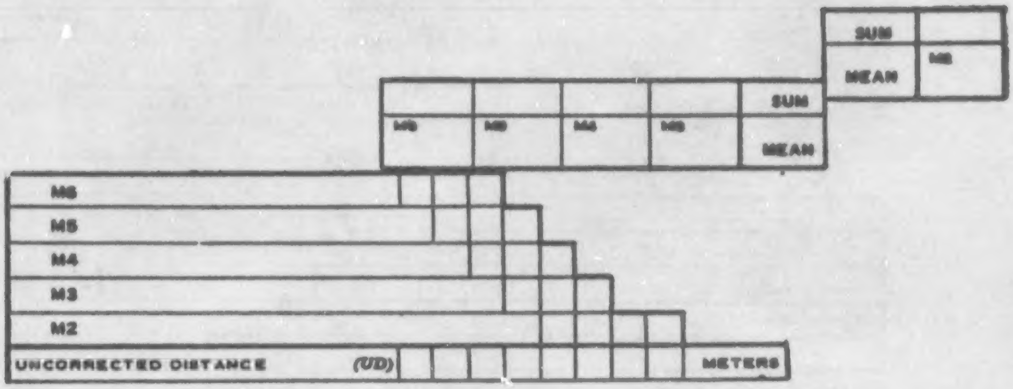
Now you are required to fill in the channel designators, M2, M3, M4, M5 and M6, both for mean values and for resolution of (UD).



FRAME 13

The M2 value is always excepted as correct (providing it meets certain criteria to be discussed later), but the remaining values are considered correct only to within ± 50 units. It then becomes possible for the correct value of an M3 reading of 719 to be anywhere between ______ and ______. This then becomes the real problem of resolving for UD.

Answer to Frame 2


SUM
MEAN
SUM
MEAN
M4
M6
M5
M4
M3
M2
UNCORRECTED DISTANCE
(UD)
METERS

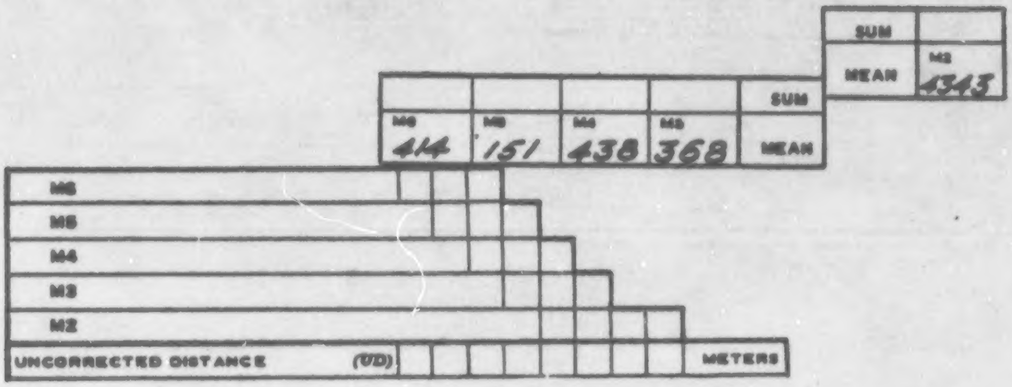
Answer to Frame 13

769 and 669

824

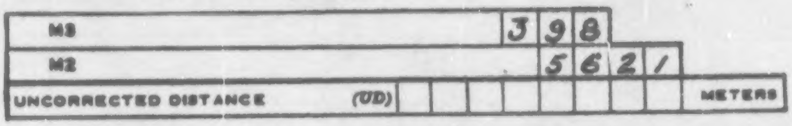
FRAME 3

Given the figure and mean channel readings as illustrated below, label, as to channel, both the mean values and the corresponding location for the values in preparation to resolving (UD). In addition, you are to correctly transfer the actual channel readings to their appropriate locations.


SUM
MEAN
M2
1343
SUM
MEAN
M6
414
M5
151
M4
438
M3
368
M6
M5
M4
M3
M2
UNCORRECTED DISTANCE
(UD)
METERS

FRAME 14

Keeping in mind the concept of the last two digits of an M value having to agree with the first two digits of the lesser M value, examine the below example.


M3
3 9 8
M2
5 6 2 1
UNCORRECTED DISTANCE
(UD)
METERS

The correct value of M3 can be between ______ and ______. Again keeping in mind the stated concept above, that is the real value of M3? ____________.

856

825

Answer to Frame 3

SUM	
MEAN	M2 4343

				SUM
M6 414	M5 151	M4 438	M3 368	MEAN

M6	4	1	4						
M5		1	5	1					
M4			4	3	8				
M3				3	6	8			
M2					4	3	4	3	
UNCORRECTED DISTANCE (UD)									METERS

Answer to Frame 14

448 and 348.

356.

857

FRAME 4

Having correctly transferred the mean values of the measurement to the resolution format, you may now begin the task of computing UD. You are justified in asking at this point, "just what units of measure do each of these values represent." A fair question - proceed to the next frame.

FRAME 15

Remember, M3, M4, M5, and M6 are accurate to ± 50 units, and the last two digits of each must agree with ____________________ of the next lowest M value. Solve for the correct reading of M4 in the problem below.

M4			5	0	2				
M3				3	9	8			
M2									
UNCORRECTED DISTANCE (UD)									METERS

Correct M4 value is __________.

Answer to Frame 15

the first two digits (or words meaning the same)

539

FRAME 5

The M2 value is in terms of millimeters. Based on your knowledge of the metric system, convert an M2 value of 4319 millimeters to meters.

____

FRAME 16

Let's see how well you've followed. Below is a rather unique situation, see what you can do with it. The object is to determine the correct M5 and M6 values.

M6	2	7	4						
M5		6	9	6					
M4			4	5	1				
M3									
M2									
UNCORRECTED DISTANCE (UD)									METERS

M5 = ____________________

M6 = ____________________

Answer to Frame 5

4.319

Answer to Frame 16

745

274

FRAME 6

Even though the M2 value is in ___________, it is not logical to speak of a long distance in these terms, and consequently we convert to ____________, which is a more convenient term.

FRAME 17

Did you get 745 as your answer? If so, you're exceptionally alert. If you didn't, that's Ok too, as this example was a bit difficult, and we haven't discussed changing the first digit of an M reading in order to make the "last two" digit agreement between it and the lesser channel reading. Remember, the last two digits of an M value must agree with the first two digits of the lesser channel, even though the first digit might change. M values are accurate to ± 50 units, and it's very possible that the first digit may change when finding the "real" value.

GO TO THE NEXT FRAME

831

Answer to Frame 6

millimeters, meters

FRAME 7

The M2 value then is converted to meters by multiplying its usual measurement unit ____________, by the factor 0.001.

FRAME 18

Study the problem below, and then have a go at resolving M2, 3 and 4.

M4			3	0	2				
M3				6	3	9			
M2					0	4	2	/	
UNCORRECTED DISTANCE (UD)									METERS

M2 ________________
M3 ________________
M4 ________________

Answer to Frame 7

millimeters

Answer to Frame 18

M2	0421
M3	604
M4	260

FRAME 8

The remaining channel values each add an additional significant digit to the left of the decimal established in the M2 value. Since M2 provides the single (or ones) unit, then the M3 would be in units of ten meters and M4 in units of __________ meters, etc.

FRAME 19

Having mastered the "art" of resolving each "M" value in terms of the previous value, it remains only to "put it all together" in order to arrive at the uncorrected distance.

Study the format below at left and relate it to the "scratch paper" resolution at the right.

M6	414
M5	143
M4	434
M3	343
M2	4343

Resolution of "real" M values

M6	4	/	4						
M5		/	5	/					
M4			4	3	8				
M3				3	6	8			
M2					4	3	4	3	
UNCORRECTED DISTANCE (UD)	4	/	4	3	4	3	4	3	METERS

Answer to Frame 8

one hundred

867

FRAME 9

If an M2 value of 4615 equals 4.615 meters, and an M3 value of 346 represents 34.6 meters, then an M4 value of 834 is representative of ________ meters. This pattern continues through M6 where a value of 108 would be representative of ________ meters.

FRAME 20

In the last frame, you saw again the solution of individual M resolutions, but for the first time saw a complete solution to the problem. You were again reminded of the relationship that exists between successive M values, and you should have noticed that the M2 value was transposed unchanged, directly to the UD line, while the actual M readings were changed or resolved to real readings to facilitate the "agreement rule."

GO TO THE NEXT FRAME

Answer to Frame 9

834, 10,800

FRAME 10

A distance of 718 meters would be represented by a value of 718 for M4, while a distance of 3718 would be represented by a value of 371 for M___.

FRAME 21

In the example below, you are to utilize the provided coarse readings on the left and complete the "scratch paper" resolution to the right. Upon completion it should be clear as to what digit(s) of the M values are brought to the UD line. After completion, check your answer on the next page and proceed to the next frame.

M6	0	0	9						
M5		3	9	6					
M4			7	0	9				
M3				2	1	5			
M2					0	3	9	7	
UNCORRECTED DISTANCE (UD)									METERS

839

Answer to Frame 10

M5

Answer to Frame 21

M6		0	0	9						
M5			3	9	6					
M4				7	0	9				
M3					2	1	5			
M2						0	3	9	7	
UNCORRECTED DISTANCE	(UD)	0	3	7	2	0	3	9	7	METERS

M6	037
M5	372
M4	720
M3	203
M2	0397

871

FRAME 11

Using the distance 46,341.072, write the corresponding value for the indicated M values.

M2__________
M3__________
M4__________
M5__________
M6__________

FRAME 22

How did you make out? If you were correct, you're "hanging in there," but if you're still a bit unsure, review frames 13 thru 21.

GO TO THE NEXT PAGE

Answer to Frame 11

M2	1072
M3	410
M4	341
M5	634
M6	463

GO BACK TO PAGE 3

842

SUMMARY

You have been exposed to the resolution of coarse readings in order to determine UD in the completion of this text.

Remember that the coarse readings are correct to within ± 50 units, while the M2 value is considered correct, and that it is the first digit of the M3 thru M6 readings that comprise UD along with the complete M2 value.

Now, test your knowledge of the resolution process by completing the criterion test on page 26.

874

843

CRITERION TEST

Resolve without mistakes the coarse readings below to determine Uncorrected Distance (UD).

SUM	
MEAN	M2 2107

				SUM
M6 095	M5 662	M4 019	M3 456	MEAN

M6										
M5										
M4										
M3										
M2										
UNCORRECTED DISTANCE (UD)										METERS

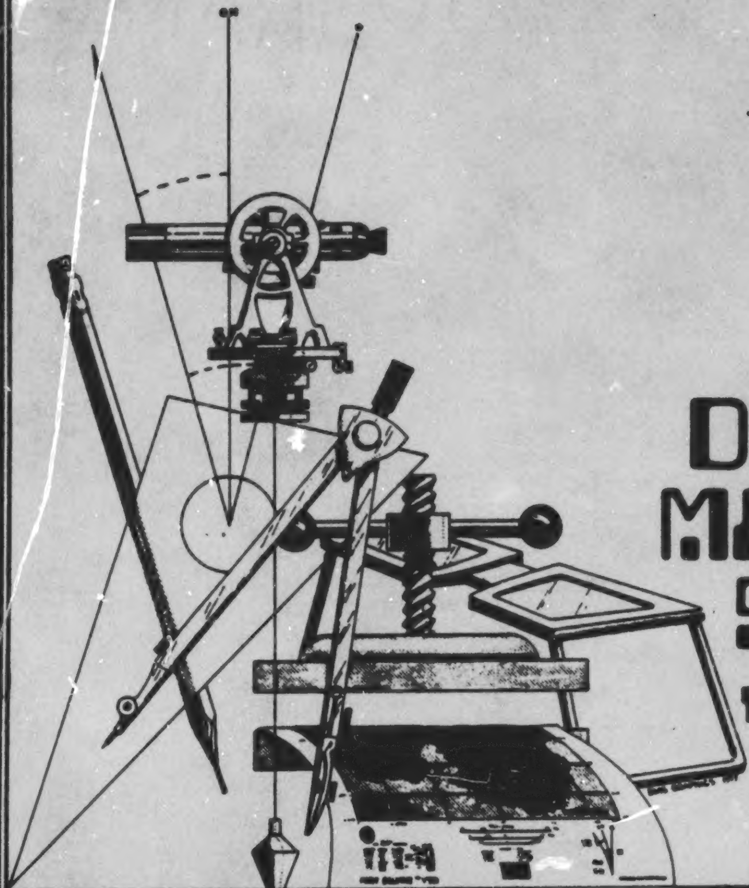
GO TO PAGE 4 FOR SOLUTION OF THE CRITERION TEST

875

PROGRAMMED LESSON

DMS NO. PI 118

DETERMINATION OF STADIA CONSTANT



DEFENSE
MAPPING
SCHOOL

FORT BELVOIR
VIRGINIA

OCT 1977

845

DETERMINATION OF STADIA CONSTANT

Programmed Lesson

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Introduction -- i

Instructions to Students ------------------------------------ ii

Objectives of Lesson -- iii

Lesson Frames -- 1-18

Self-Test -- 19-20

INTRODUCTION

The stadia constant of a precise level is the multiplication factor used in conjunction with the rod intervals to determine the stadia length of a level line, and the allowable error. In the supply system today there are levels that are identical in all aspects except, the stadia constant. Thus, the surveyor and the instrument repairman must know how to correctly determine the stadia constant of a precise level.

DETERMINATION OF STADIA CONSTANT

INSTRUCTIONS TO STUDENTS

This is a programmed lesson, not a test. The information is broken down into small bits called "frames" which are followed by an incomplete "response." Study the frame until you can complete the missing portion of the response; then check your answer with the correct answer which is printed on the next page. If your answer does not agree, re-study the frame, or, ask the instructor for assistance.

This booklet is your property; make notes in it where you think they are needed. Your answers are for your information and are not a test other than self-testing to see if you understand the "response."

One hour of class time has been alloted for this lesson and PE, so pace yourself accordingly. Begin the lesson and read each frame carefully, then provide the required response. After responding, turn the page and check the accuracy of your response. If your initial response was incorrect, re-read the frame before continuing. Beginning on page 1, follow the top level of frames to page 18, then return to page 1, and begin the next level, continuing in this manner until all the frames have been completed.

An instructor will assist you if the need arises.

Now begin with Frame 1 at the top of page 1.

DETERMINATION OF STADIA CONSTANT

OBJECTIVES OF THIS LESSON

Upon completion of this text, the student will be able to determine the stadia constant for a level. Specifically:

a. Identify when it is necessary to determine the stadia constant.

b. List the importance of knowing the stadia constant.

c. Demonstrate how to lay-out and measure the course.

d. Demonstrate how to determine the thread interval.

e. Compute the stadia constant.

f. Mathematically check the stadia constant.

849

1. Extreme care must be exercised when handling topographic surveying instruments. A SEVERE JOLT may affect the stadia constant of a level. The stadia constant could change if the instrument has been ____________________.

9. The stadia constant is derived from a series of rod readings taken from SIX POINTS. The rod is placed and read on __________ points.

17. The sum of the top and bottom intervals is the thread interval for each point. To get the thread interval for each point you add the ________ and ___________ intervals. (See fig. 1, Col D.)

24. After the constant has been determined for the first point, you continue until a constant is determined for EVERY POINT of the course. For every point of the course you must determine a ____________________.

158

850

1. jolted

9. six

17. top, bottom

24. constant

882

2. The placement of the OBJECTIVE LENS in a level is the major item affecting the stadia constant. The controlling item which affects the stadia constant is the placement of the

_________________ _________________.

10. Stakes are set at six points, 25, 35, 45, 55, 65, and 75 METERS in line, and measured from the focal point of the instrument. The distances for the stadia constant course are measured from the _____________ _____________. (See fig. 1, Col A, p 7.)

18. Once the thread interval for each point of the course has been determined, ADD all SIX together to determine the sum of intervals. The sum of intervals is found by ____________ all six intervals. (See fig. 1, Col D.)

25. After a constant has been determined for each point of the course, you then add all constants together and divide by six, the number of points in the course. You must determine a separate constant for each of the ____________ measured points of the course. (See fig. 1, Col F.)

2. objective lens

10. focal point

18. adding

25. six

3. The stadia constant IS NOT the same for all levels. Therefore, is it proper to say that all levels have the same stadia constant? ____________.
(Yes - No)

11. At each point of the course, three ROD READINGS must be taken and recorded; they are the bottom, middle, and top wire. Three wire readings are taken on the ____________ at each point. (See fig. 1, Col B.)

19. To determine the SUM of the DISTANCES, add all the distances of the course. If this is done correctly, they will equal 300 meters (25+35+45+55+65+75=300 meters). By adding all the distances you determine the ________________ of the distances. (See fig. 1, Col A.)

26. After dividing the sum of the six constants by six, your quotient should be in close agreement with your previously determined stadia constant (±.001). This is your check for the previously determined stadia constant. Is it true that your check will always agree closely with your previously determined stadia constant? ______
(Yes - No)

THIS COMPLETES THE LESSON. GO TO PAGE 19 AND TAKE THE SELF-TEST.

3. No

Continue on page 9

11. rod

Continue on page 9

19. sum

Continue on page 9

26. Yes

GENERAL SURVEY NOTES

PROJECT Determination of Stadia Constant

LOCATION Ft. Belvoir, VA

DESIGNATION

WEATHER

WIND

TEMP

INSTRUMENT

DATE 3 Oct 1977

ORGANIZATION DMS

PAGE NO. 1

NO OF PGS. 2

Station	Thread Reading		Interval	Σ Intervals							
(A)	(B)		(C)	(D)		(E)		(F)			
	1722										
25	1597		125								
	1471		126	251		$\frac{25}{251}$ =	0.0996 =	0.100			
	1860										
35	1685		175								
	1510		175	350		$\frac{35}{350}$ =	0.1000 =	0.100			
				601							
	1989										
45	1763		226								
	1539		224	450		$\frac{45}{450}$ =	0.1000 =	0.100			
				1051							
	2134										
55	1859		275								
	1583		276	551		$\frac{55}{551}$ =	0.0998 =	0.100			
				1602							
	2138										
65	1812		326								
	1488		324	650		$\frac{65}{650}$ =	0.1000 =	0.100			
				2252					(con't on next page)		

DMS Form 24 (4 Feb 74)

Figure 1

⊼	PROJECT Determination of Stadia Constant	WEATHER	GENERAL SURVEY NOTES		
♉	LOCATION Ft. Belvoir, VA	WIND	INSTRUMENT	DATE 3 Oct 1977	
∅	DESIGNATION	TEMP	ORGANIZATION DMS	PAGE NO. 2	NO OF PGS. 2

Station	Thread Reading		Interval	Σ Intervals							
(A)	(B)		(C)	(D)		(E)		(F)			
	2275										
75	1900		375								
	1525		375	750		75 =	0.1000	0.100			
				3002		750					
								0.600 ÷	6 = 0.100 ✓		
300 =	0.0999 =	0.100									
3002											

8

DMS Form 24 (4 Feb 74)

Figure 1 (con't)

4. The stadia constant MUST BE determined before starting a survey project. At the beginning of a survey project, or when first placing the level in service you must determine the ______________________.

12. Three wire readings are taken on the rod at six points, measured from the focal point of the instrument. This is the stadia constant course. The stadia constant course is comprised of ____________ points measured from the ______________________________ of the instrument.

20. The sum of the intervals DIVIDED INTO the sum of the distances will give you the stadia constant. The sum of the distances ______________ by the sum of the intervals will give you the stadia constant.

4. stadia constant

12. six, focal point

20. divided

5. The stadia constant must be determined before placing a level in service, or any time the objective lens has been disturbed. If the objective lens has bean disturbed and/or prior to a survey project, you must determine the ________ ________.

13. The purpose of taking THREE wire readings at each point is to provide information to determine the thread intervals. The information used to determine the thread intervals is derived from the ________ wire readings.

21. The stadia constant is determined by dividing the sum of the intervals into the sum of the distances. When the sum of the intervals is divided into the sum of the distances, your quotient is the ________ ________.

5. stadia constant

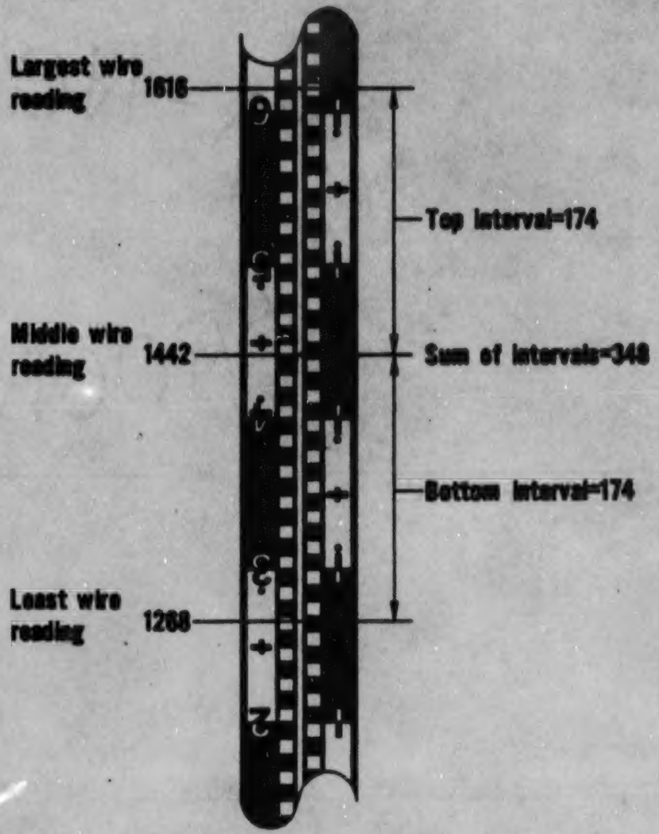
13. three

21. stadia constant

Continue on page 15

6. The STADIA DISTANCE of a level line must be known before the allowable error can be determined. To determine the allowable error you must know the ____________ ______________.

14. Thread INTERVALS are determined by subtracting the least wire reading from the middle wire reading, and subtracting the middle wire reading from the largest wire reading. For each point of the course you must determine ______________ thread intervals. (See fig. 2.)


Largest wire reading
1616
Top interval=174
Middle wire reading
1442
Sum of intervals=348
Bottom interval=174
Least wire reading
1268

6. stadia distance

14. two, or 2

7. Once determined, the STADIA CONSTANT is the multiplication factor used to determine stadia distance. To determine stadia distance you use the _______ ____________.

15. When the least wire reading is subtracted from the middle wire reading, and the middle wire reading from the largest wire reading, they MUST AGREE within 0.003 meters. The bottom interval must agree with the top interval within _________ meters. (See fig. 1, Col C.)

22. Once determined, the stadia constant MUST be CHECKED to verify that your computations are correct. The stadia constant is not considered correct until a _________________ has been made.

7. stadia constant

15. .003 meter

22. check

899

8. The stadia constant is used to determine the length of a level line, and the length of the line is used to determine the allowable error. In order to determine the length and the allowable error of a level line you must know the __________ ____________.

16. If the bottom and top intervals do not agree within .003 of a meter, the ROD must be REOBSERVED for accuracy. If the intervals fail to meet the required accuracy the ____________ must be ______________.

23. To perform the check for the stadia constant you must divide the measured distance to EACH POINT by the sum of intervals for that POINT. To begin the check, you divide the measured distance by the sum of intervals for each ________________. (See fig. 1, Col E.)

866

8. stadia constant

GO BACK TO PAGE 1 FOR FRAME 9

16. rod, reobserved

GO BACK TO PAGE 1 FOR FRAME 17

23. point

GO BACK TO PAGE 1 FOR FRAME 24

900

867

⊼	PROJECT Determination of Stadia Constant	WEATHER	**GENERAL SURVEY NOTES**	
Ʊ	LOCATION Ft. Belvoir, VA	WIND	INSTRUMENT	DATE 3 Oct 1977
∅	DESIGNATION Self Test	TEMP	ORGANIZATION DMS	PAGE NO. 1 / NO. OF PGS. 2

19

Station	Thread Reading		Interval	Σ Intervals							
(A)	(B)		(C)	(D)		(E)		(F)			
	1718										
25	1593										
	1468										
	1859										
35	1685										
	1509										
	1985										
45	1760										
	1535										
	2130										
55	1855										
	1581										
	2135										
65	1809										
	1485										
									(con't on next page)		

DMS Form 24 (4 Feb 74)

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⊼	PROJECT Determination of Stadia Constant	WEATHER	**GENERAL SURVEY NOTES**
⛉	LOCATION Ft. Belvoir, VA	WIND	INSTRUMENT / DATE 3 Oct 1977
ø	DESIGNATION Self Test	TEMP	ORGANIZATION DMS / PAGE NO. 2 / NO. OF PGS. 2

Station	Thread Reading		Interval	Σ Intervals							
(A)	(B)		(C)	(D)		(E)		(F)			
	2271										
75	1896										
	1522										

DMS Form 24 (4 Feb 74)

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PROGRAMMED LESSON

DETERMINATION OF C

DEFENSE
MAPPING
SCHOOL

FORT BELVOIR
VIRGINIA

MAY 1978

DETERMINATION OF "C"

INSTRUCTIONS TO STUDENTS

This program text is a unit of work which involves "Self Teaching." The overall lesson information is broken into small steps called "frames." Each frame instructs with words, sample problems, or both, then requires you to apply that bit of instruction by completing a response or doing a described action. The booklet is set up so that the answers to each frame are on the following page.

To work and learn with this booklet, you read the frame and complete the response or problem, then turn to the next page to check your answer. It is there for verification, NOT for COPYING. When that frame is completed successfully, go to the next frame in numerical sequence.

This lesson may be given as a classroom exercise or it may be given as a homework assignment. If you are in the classroom and need help, raise your hand and an instructor will assist you. If the exercise is given as a homework assignment and there is no instructor available to assist you in arriving at the correct answer, go back and review the previous frames. You may have missed a point. This program text is to be completed only after you have completed the lessons on level notekeeping and stadia factor determination.

INTRODUCTION

Each day, just before the leveling is started or immediately after the beginning of the day's observations and immediately following any instance when the level is subjected to unusual shock, the error of the level ("C") must be determined. The required "C" determined is basically the ratio of the required rod reading correction to the corresponding subtended interval or

$$C = \frac{(\text{sum of near rod readings}) - (\text{sum of far rod readings})}{(\text{sum of far rod intervals}) - (\text{sum of near rod intervals})}$$

The maximum permissible "C" varies with the stadia factor of the instrument. The instrument must be adjusted at once if the "C" is greater than 0.004 for instruments with a stadia factor of approximately 0.100, 0.007 for a stadia factor of 0.200, and 0.010 for a stadia factor of 0.333. The most common level is one with a stadia factor of 0.100; therefore, the information contained in this lesson will apply to the 0.100 stadia factor. Determination of the "C" for instruments with a 0.200 or 0.333 stadia factor is accomplished in the same manner outlined in this lesson. The information contained in this lesson can be applied to either of the other instruments.

871

FRAME 1

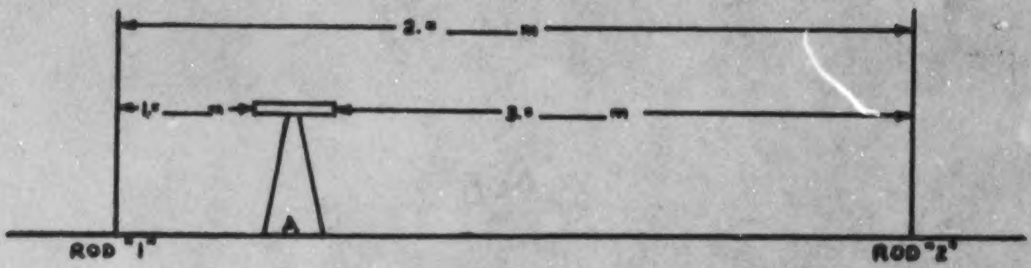


DIAGRAM OF INSTRUMENT SET UP
FOR DETERMINATION OF "C"

1. Select an area that is fairly flat, clear and at least 85 meters in length.
2. Drive the turning pin for Rod "1" in the ground and pace off approximately 10 meters and set up your instrument. (Set up at position A.)
3. Have the second rodman pace approximately 75 meters from the instrument in the opposite direction of Rod "1" and drive his turning pin in the ground. This will be Rod "2."
4. You now have a total approximate distance of 85 meters between the two rods.
5. Setting up and reading the instrument is accomplished by the same procedures which you have previously learned.

After reading the above information, place the appropriate distances in the spaces of the above diagram.

907

Answers to Frame 1: 1. = 10 meters
2. = 85 meters
3. = 75 meters

FRAME #2

In Frame 1, you were required to set the instrument _____ meters from Rod "1".

908

873

Answer to Frame 2: 10 meters

FRAME 3

The total distance from Rod "1" to Rod "2" is __________ meters.

909

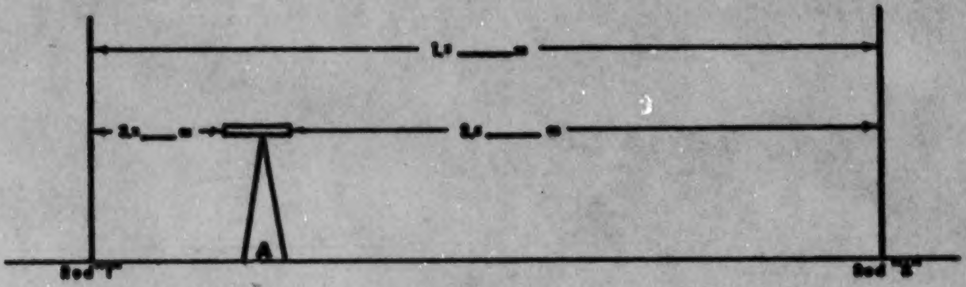
Answer to Frame 3: 85 meters

FRAME 4

It is 75 meters from the instrument to ________________.

Answer to Frame 4: Rod "2"

FRAME 5


1. ___ m
2. ___ m
3. ___ m
A
Rod "1"
Rod "2"

In the above diagram, give the required distances between the rods and between the instrument and the rods.

Answer to Frame 5:
1. = 85 meters
2. = 75 meters
3. = 10 meters

FRAME 6

If you have completed Frame 5 without error, proceed to Frame 7. If you have made an error, read again Frames 1 through 5.

FRAME 7

At this point, the instrumentman is set up and ready to take the first rod readings. Recalling your class on notekeeping, 3 wire readings must meet certain specifications. This specification for third-order stated that the difference in rod interval between the middle and top wire and the middle and bottom wire must not exceed 0.003.

1. Using this criteria, are the backsight readings on the illustration below within the tolerance of the specification? __________
2. On which rod do you take your first reading? 1 or 2
3. What is the allowable difference of rod interval for 3 wire readings? __________

3 WIRE LEVELING

PROJECT 30/US/311/3/77
LOCATION FT. BELVOIR, VA.
ORGANIZATION 30TH ENGR BN
OBSERVER SP 4 SMITH
RECORDER YOU
INSTRUMENT MIL. LEVEL #1927
SUN 7
WIND 0
WEATHER CLEAR, COOL
FROM
TO
DATE 24 APR 77
TIME 0745
LINE OR NET "C" CHECK
PAGE NO. 21
NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821										STADIA FACTOR
	1771										= 0.100
	1721										

Answer to Frame 7:
1. Yes
2. 1
3. .003

FRAME 8

After determining that the readings on rod "1" are good, the instrumentman will read rod "2."

Are the foresight readings on the illustration below within tolerance? ___________

PROJECT 30/63/344/3/77	LOCATION FT. BELVOIR, VA	ORGANIZATION 30TH ENGR BN	**3 WIRE LEVELING**
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT MK. LEVEL # 1487	SUN 7 · WIND 0 · WEATHER CLEAR, COOL
FROM · TO	DATE 26 APR 77	TIME 0745	LINE OR NET "C" CHECK · PAGE NO. 21 · NO OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1059					STADIA FACTOR
	1771			050		0939					= 0.100
	1721			050		0819					

Answer to Frame 8: No, Because: 374

370

Difference: 004

FRAME 9

After determining that the 3 wire readings on Rod "2" were not within tolerance, the instrumentman again reads Rod "2."

Are the new foresight readings on the illustration below within tolerance? ____________

PROJECT 30/US/311/3/77	LOCATION FT. BELVOIR, VA	ORGANIZATION 30TH ENGR BN	3 WIRE LEVELING
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT WH. LEVEL # 1437	SUN 7 · WIND 0 · WEATHER CLEAR, COOL
FROM · TO	DATE 26 DEC 77 · TIME 0745	LINE OR NET "C" CHECK	PAGE NO. 21 · NO. OF POL.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1054					STADIA FACTOR
	1771			050		0680			374		= 0.100
	1721			050		0310			370		
											REREAD
											ROD 2

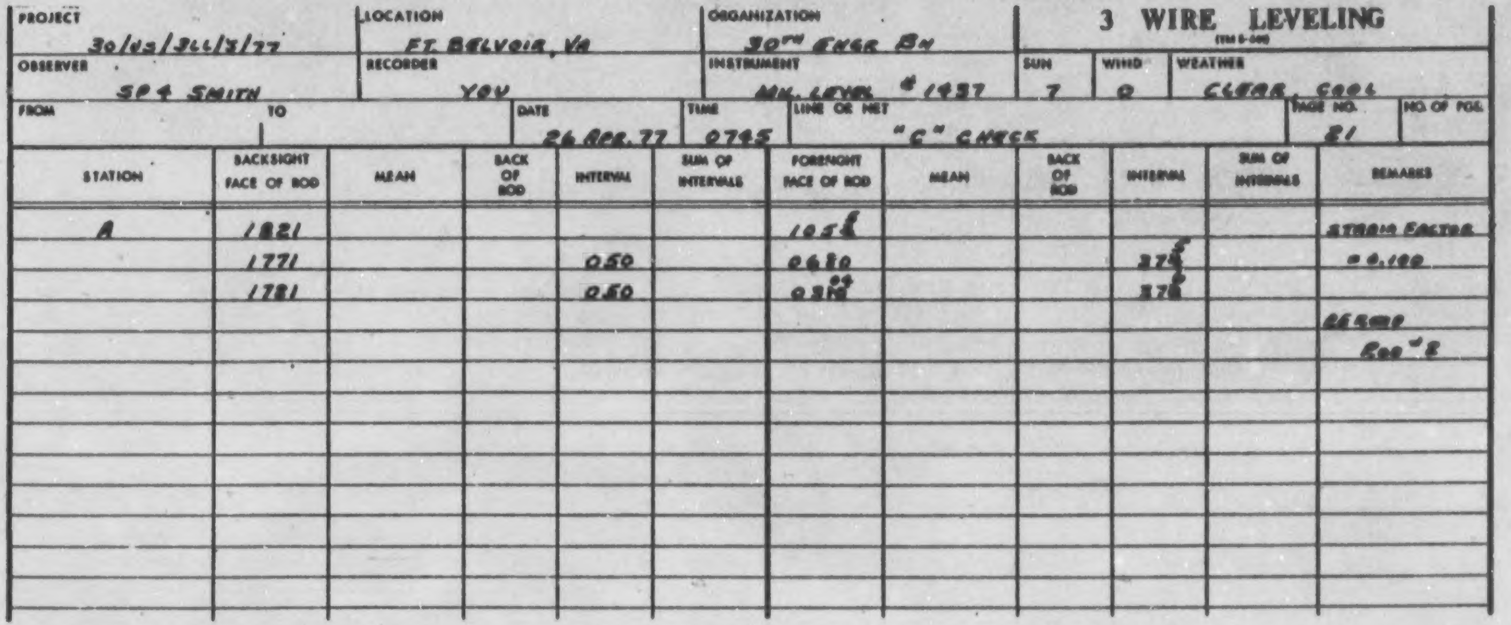
Answer to Frame 9: Yes, Because: 375
376
Difference: 001

FRAME 10

You have now completed the first set-up for determining the "C" of your instrument and are ready to move within 10 meters of Rod "2" for the second set-up. Before moving, determine the mean for the BACKSIGHT AND FORESIGHT below. These means and sums of intervals are found in the same manner as you learned in previous lessons on third-order level notekeeping.

On the illustration below, compute the following:

A. Sum of Intervals, BS	C. Mean BS Reading	E. Summation BS Readings
B. Sum of Intervals, FS	D. Mean FS Reading	F. Summation FS Readings



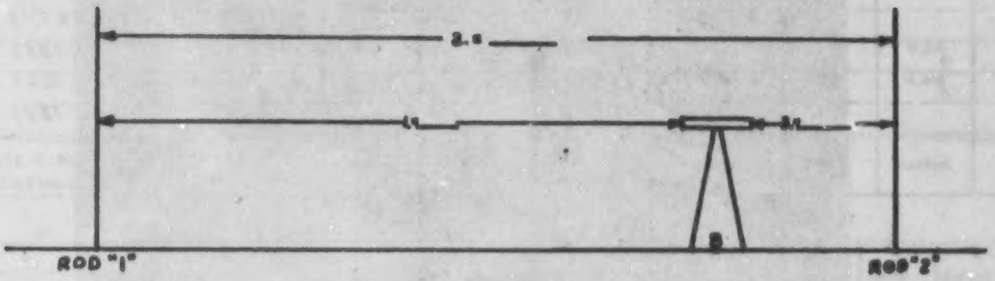
3 WIRE LEVELING

PROJECT 30/US/3LL/3/77	LOCATION FT. BELVOIR, VA	ORGANIZATION 30TH ENGR BN	
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT MK. LEVEL #1457	SUN 7 / WIND 0 / WEATHER CLEAR, COOL
FROM / TO	DATE 26 APR. 77 / TIME 0745	LINE OR NET "C" CHECK	PAGE NO. 21 / NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1055					STADIA FACTOR
	1771			050		0680			375		= 0.100
	1721			050		0304			376		
											BEHIND
											ROD #2

Answer to Frame 10:
A. = 100
B. = 751
C. = 17710
D. = 06797
E. = 5313
F. = 2039

FRAME 11



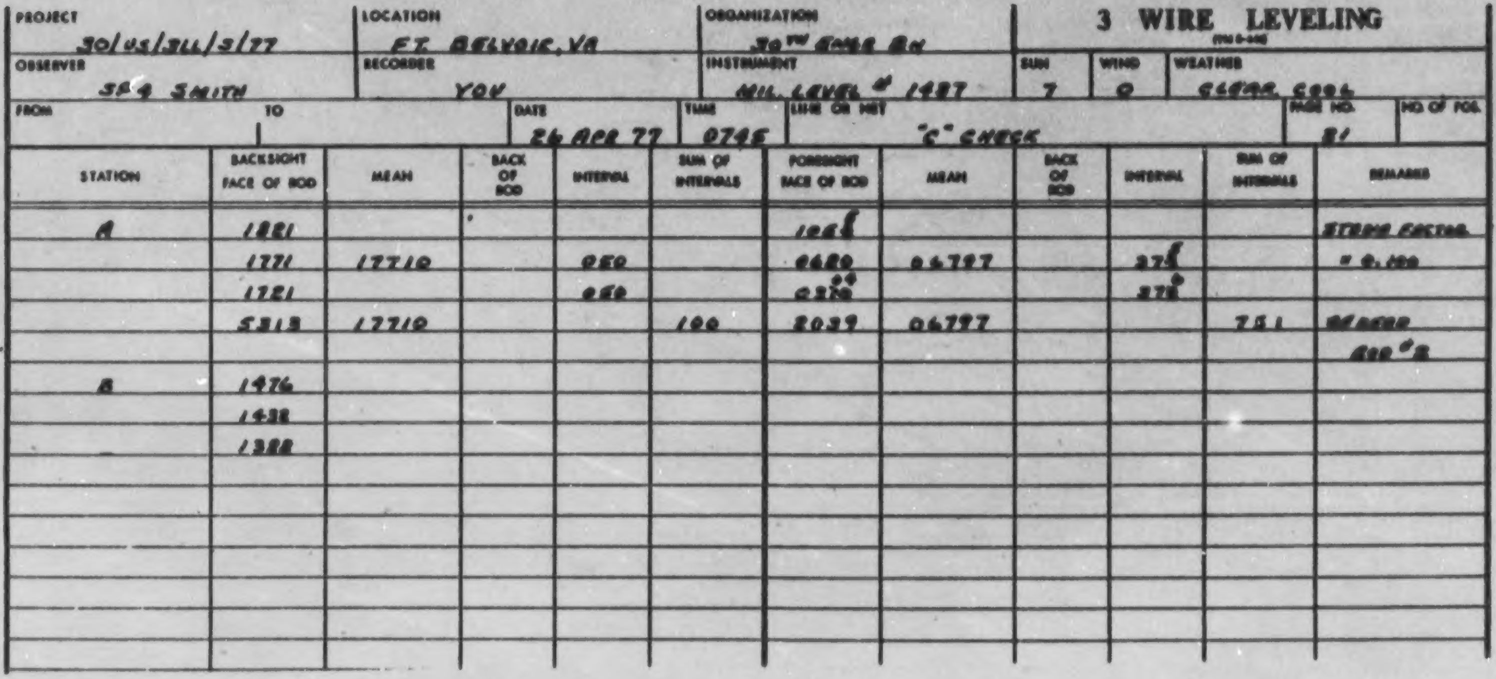
The distances for the second set-up, (B), are the same as for set-up (A). Knowing this criteria, fill in the distances for set-up (B) in the spaces provided on the illustration above.

Answer to Frame 11: 1 = 75 meters
2 = 85 meters
3 = 10 meters

FRAME 12

The instrumentman has set up, leveled the instrument in the "B" position and read Rod "2."

Are the new backsight readings in the illustration below acceptable? __________



3 WIRE LEVELING

PROJECT 30/US/311/3/77
LOCATION FT. BELVOIR, VA
ORGANIZATION 30TH ENGR BN
OBSERVER SP4 SMITH
RECORDER YOU
INSTRUMENT MIL. LEVEL # 1487
SUN 7
WIND 0
WEATHER CLEAR, COOL
FROM
TO
DATE 26 APR 77
TIME 0745
LINE OR NET "C" CHECK
PAGE NO. 21
NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1055					STADIA FACTOR
	1771	17710		050		0680	06797		375		= 0.100
	1721			050		0304			376		
	5313	17710			100	2039	06797			751	READER
											ROD # 2
B	1476										
	1432										
	1388										

Answer to Frame 12: Yes, Because: 044
044
Difference: 000

FRAME 13

Next the instrumentman reads Rod "1."

Are the new foresight readings on the illustration below within tolerance? If so, compute the mean readings, intervals, sum of intervals, and accumulative column totals on the illustration below.

3 WIRE LEVELING

PROJECT 30/US/311/3/77
LOCATION FT. BELVOIR, VA
ORGANIZATION 30TH ENGR BN
OBSERVER SP4 SMITH
RECORDER YOU
INSTRUMENT MIL LEVEL # 1437
SUN 7
WIND 0
WEATHER CLEAR, COOL
FROM
TO
DATE 26 APR. 77
TIME 0745
LINE OR NET "C" CHECK
PAGE NO. 21
NO OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1055					STADIA FACTOR
	1771	17710		050		0680	06797		375		X 0.100
	1721			050		0304			376		
	5313	17710			100	2039	06797			751	REREAD
											ROD #2
B	1476					2908					
	1432			044		2530					
	1388			044		2154					

884

Answer to Frame 13: Yes, Because: 378
376
Difference: 002

FRAME 14

You have now determined that all readings are good and have meaned the backsights and foresights. If your Frame 13 looks like the example below, move to Frame 15. If it doesn't, go back and review the material covered to this point.

PROJECT 30/US/366/3/77	LOCATION FT BELVOIR VA	ORGANIZATION 30TH ENGR BN	3 WIRE LEVELING
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT MIL. LEVEL # 1437	SUN 7 · WIND 0 · WEATHER CLEAR, COOL
FROM · TO	DATE 26 APR 77 · TIME 0745	LINE OR NET "C" CHECK	PAGE NO. 21 · NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1055					STADIA FACTOR
	1771	17710		050		0680	06797		375		= 0.100
	1721			050		0304			376		
	5313	17710			100	2039	06797			751	REFERR
											ROD #2
B	1476					2908					
	1432	14320		044		2530	25307		378		
	1388			044	088	2154			376	754	
	9609	32030			188	9631	32104			1505	

927

926

885

FRAME 15

To test your newly acquired knowledge for "C" determination, compute the mean readings, intervals, sums of intervals, and accumulative column totals for both the backsight and foresight readings on the sample below.

PROJECT 30/03/311/3/77	LOCATION FT. BELVOIR, VA	ORGANIZATION 30TH ENGR BN	3 WIRE LEVELING (TM 5-441)		
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT MIL LEVEL # 1487	SUN 7	WIND 0	WEATHER CLEAR, COOL
FROM / TO	DATE 26 APR 77	TIME 0745	LINE OR NET "C" CHECK	PAGE NO. 81	NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1642					2002					STADIA FACTOR
	1593					1655					= 0.100
	1545					1308					
B	1588					1883					
	1537					1507					
	1487					1133					

886

Answer to Frame 15: If your work looks like the problem below, you understand "C" determination thus far and are ready to proceed.

PROJECT 30/63/311/3/77	LOCATION FT. BELVOIR, VA	ORGANIZATION 30TH ENGR BN	**3 WIRE LEVELING**
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT MIL. LEVEL #1987	SUN 7 · WIND 0 · WEATHER CLEAR, COOL
FROM · TO	DATE 26 Apr. 77 · TIME 0745	LINE OR NET "C" CHECK	PAGE NO. 21 · NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1642					2002					STADIA FACTOR
	1593	15933		049		1628	16277		374		= 0.100
	1545			048		1253			375		
	4780	15933			097	4883	16277			749	
B	1588					1883					
	1537	15373		051		1507	15077		376		
	1487			050	101	1133			374	750	
	9392	31306			198	9406	31354			1499	

FRAME 16

Since you have completed the check above, you are ready for the next step. That is the determination of a curvature and refraction correction. PROCEED TO FRAME 17.

930

931

887

FRAME 17

Now that you have meaned your readings and have totaled your intervals, you are ready to determine and apply a curvature and refraction correction, which is applied to each of the far rod readings only. To simplify this step, there is a table of Curvature and Refraction below for distances from 0 to 200 meters. Since your distances will always fall near 75 meters, this table can always be used for the "C" Check of your instrument.

In looking at the table, you will note that there is no correction for distances up to 28 meters. This means that in determining the "C" of your instrument, the correction will always be applied to the foresight readings.

The argument for entering the table is the distance for each foresight. The distance is obtained by multiplying the total rod interval for each foresight by the stadia interval factor (SIF) for that instrument. The SIF should be noted in the remarks column of the field notes. The individual correction, as obtained from the table, may be inserted in the "Back of Rod" column adjacent to each foresight.

Using the table shown below and the illustration on the next page, determine the curvature and refraction correction for the problem on the next page.

a. The Foresight distance for the first set-up is ______.
b. The Foresight distance for the second set-up is ______.
c. The curvature and refraction correction for the first set-up is ______.
d. The curvature and refraction correction for the second set-up is ______.
e. The total curvature and refraction correction is ______.

Distance meters	Correction to rod mm.	Distance meters	Correction to rod mm.
0 to 27	0.0	125 to 130	-1.1
28 to 47	-0.1	131 to 136	-1.2
48 to 60	-0.2	137 to 141	-1.3
61 to 72	-0.3	142 to 146	-1.4
73 to 81	-0.4	147 to 150	-1.5
82 to 90	-0.5	160	-1.8
91 to 98	-0.6	170	-2.1
99 to 105	-0.7	180	-2.3
106 to 112	-0.8	190	-2.6
113 to 118	-0.9	200	-2.8
119 to 124	-1.0		

932

PROJECT	LOCATION	ORGANIZATION	3 WIRE LEVELING (TM 5-441)		
30/US/3LL/3/77	FT. BELVOIR, VA.	30TH ENGR BN			
OBSERVER	RECORDER	INSTRUMENT	SUN	WIND	WEATHER
SP4 SMITH	YOU	MK LEVEL # 1437	7	0	CLEAR, COOL

FROM	TO	DATE	TIME	LINE OR NET	PAGE NO.	NO. OF PGS.
		26 APR. 77	0745	"G" CHECK	21	

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1055					STADIA FACTOR
	1771	17710		050		0680	06797		375		= 0.100
	1721			050		0304			376		
	5313	17710			100	2039	06797			751	ALBERD
											ROD # 2
B	1476					2908					
	1432	14320		044		2530	25307		378		
	1388			044	088	2154			376	754	
	9609	32030			188	9631	32104			1505	

934

933

Answer to Frame 17:
a. = 75.1m
b. = 75.4m
c. = -0.4mm
d. = -0.4mm
e. = -0.8mm

FRAME 18

Now that you have the total curvature and refraction correction, it is applied to the total of the mean foresight readings and is always subtracted. This correction must be applied before proceeding.

Using the correction you computed in Frame 17, apply it to the readings below:

3 WIRE LEVELING

PROJECT: 30/US/344/5/77
LOCATION: FT. BELVOIR, VA
ORGANIZATION: 30TH ENGR BN
OBSERVER: SP4 SMITH
RECORDER: YOU
INSTRUMENT: MIL LEVEL #1937
SUN: 7
WIND: 0
WEATHER: CLEAR, COOL
FROM:
TO:
DATE: 26 APR 77
TIME: 0745
LINE OR NET: "C" CHECK
PAGE NO. 21
NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1055					STADIA FACTOR
	1771	17710		050		0680	06797	-0.4	375		=0.100
	1721			050		0304			376		
	5313	17710			100	2039	06797			751	[illegible]
											ROD #2
B	1476					2908					
	1432	14320		044		2530	25307	-0.4	378		
	1388			044	088	2154			376	754	
	9609	32030			188	9631	32104			1505	

PROJECT 30/US/8LL/S/77	LOCATION FT. BELVOIR, VA.	ORGANIZATION 30th ENGR BN	3 WIRE LEVELING (TM 5-440)
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT MIL. LEVEL #1487	SUN 7 · WIND 0 · WEATHER CLEAR COOL

FROM	TO	DATE 26 APR. 77	TIME 0745	LINE OR NET "C" CHECK	PAGE NO. 21 · NO. OF POS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1055					STADIA FACTOR
	1771	17710		050		0680	06797	-0.4	375		= 0.100
	1721			050		0304			376		
	5313	17710			100	2039	06797			751	RE READ
											ROD #2
B	1476					2908					
	1432	14320		044		2630	26307	-0.4	278		
	1388			044	088	2354			276	554	
	9609	32030			188	9931	33104			1305	
							-0.8				
							3309.6				

FRAME 19

Now that you have applied the curvature and refraction correction, the next step is to determine the value of "C." First, always subtract the smaller mean rod reading (foresight or backsight) from the larger; this will always result in a plus "C" on the left-hand page and a minus "C" on the right-hand side. Next, subtract the total backsight rod intervals from the total foresight rod intervals. At this time, using the illustration above, perform the aforementioned computations.

891

Answer to Frame 19:

3 WIRE LEVELING
(TM 5-440)

PROJECT 30/43/366/5/77
LOCATION FT. BELVOIR, VA
ORGANIZATION 30TH ENGR BN
OBSERVER SP4 SMITH
RECORDER YOU
INSTRUMENT MIL. LEVEL # 1487
SUN 7
WIND 0
WEATHER CLEAR, COOL
FROM
TO
DATE 26 APR. 77
TIME 0795
LINE OR NET "C" CHECK
PAGE NO. 81
NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1881					$105\overset{6}{5}$					STADIA FACTOR
	1771	17710		050		0680	06797	-0.4	$37\overset{6}{5}$		= 0.100
	1781			050		$031\overset{04}{0}$			$37\overset{6}{5}$		
	5313	17710			100	2039	06797			751	REREAD
											ROD #2
B	1476					2808					
	1432	14320		044		2630	25307	-0.4	378		
	1388			044	088	2154			376	754	
	9609	32030			188	9631	32104			1505	
							-0.8			188	
							3209.6			1317	
							3203.0				
							-6.6				

FRAME 20

With the accomplishment of the above, you are now ready to determine the "C" of your instrument. Divide the difference in your mean backsight and foresight readings by the difference in your backsight and foresight INTERVALS. Remember to use the interval and not the distance.

At this time, using the illustration above, compute the "C."

892

Answer to Frame 20: $\frac{-6.6}{1317}$ = C = -0.00501

FRAME 21

In comparing your computed "C" with the allowable (0.004) for this instrument, you find that the instrument must be adjusted. After adjusting the instrument, you must perform a new "C" determination to verify the adjustment.

To adjust this instrument, a correction must be applied to the last foresight reading (center wire 2530). The correction is found by multiplying the total rod interval of the last foresight reading by "C". The result of this multiplication will be in millimeters. The correction takes the sign of the difference between the backsight and foresight means, or if you have carried the sign in computing "C", it will take that sign. The correction is now applied arithmetically to your last foresight center wire reading (2530). On the example below, compute the correction and apply it:

PROJECT 30/US/3LL/5/77	LOCATION FT BELVOIR, VA.	ORGANIZATION 30TH ENGR BN	3 WIRE LEVELING
OBSERVER SP4 SMITH	RECORDER YOU	INSTRUMENT MIL. LEVEL # 1437	SUN 7 · WIND 0 · WEATHER CLEAR, COOL
FROM · TO	DATE 26 APR. 77 · TIME 0745	LINE OR NET "C" CHECK	PAGE NO. 21 · NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1821					1054					STADIA FACTOR
	1771	17710		050		0680	06797	-0.4	374		= 0.100
	1721			050		0310			376		
	5313	17710			100	2039	06797			751	REREAD
											ROD #2
B	1476					2908					
	1432	14320		044		2530	25307	-0.4	378		
	1388			044	088	2154			376	754	
	9609	32030			188	9631	32104			1505	
							-0.8			188	
							3209.6			1317	
							3203.0				
		$\frac{-6.6}{1317}$	= -0.00501 = C				-6.6				

911

912

Answer to Frame 21: 754 (rod interval) x -.00501 ("C") = -3.8mm (correction to center wire reading) = 2.530 - .004 = 2.526 (corrected rod reading)

FRAME 22

The actual adjustment of the instrument will not be covered here, but in a later lesson.

Let us now assume that this instrument has been adjusted. We must now make a new level error determination ("C") to verify your adjustment and to insure that it meets the allowable limits for your instrument.

To check the knowledge gained from this Programmed Text, compute a new "C" using the readings shown in the illustration below.

3 WIRE LEVELING

PROJECT 30/US/3LL/S/77

LOCATION FT. BELVOIR, VA.

ORGANIZATION 30TH ENGR BN

OBSERVER SP4 SMITH

RECORDER YOU

INSTRUMENT WILD LEVEL # 1437

SUN 7

WIND 0

WEATHER CLEAR, COOL

FROM

TO

DATE 26 APR. 77

TIME 0745

LINE OR NET "C" CHECK

PAGE NO. 21

NO. OF PGS.

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1569					2270					STADIA FACTOR
	1500					1915					= 0.100
	1432					1560					
B	1728					1628					
	1671					1260					
	1616					0891					

Answer to Frame 22:

If your work looks like the example below, you have correctly completed the programmed text on the "C" determination and are ready to go to the field and apply this newly acquired knowledge. If your work does not look like the example below, you have incorrectly applied the information contained within this programmed text. Go back and read again the contents of this text.

3 WIRE LEVELING (TM 5-441)

PROJECT: 30/US/366/5/77
LOCATION: FT. BELVOIR, VA.
ORGANIZATION: 30TH ENGR BN
OBSERVER: SP4 SMITH
RECORDER: YOU
INSTRUMENT: MIL. LEVEL # 1437
SUN: 7
WIND: 0
WEATHER: CLEAR, COOL
FROM:
TO:
DATE: 26 APR. 77
TIME: 0745
LINE OR NET: "C" CHECK
PAGE NO.: 21
NO OF POL.:

STATION	BACKSIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	FORESIGHT FACE OF ROD	MEAN	BACK OF ROD	INTERVAL	SUM OF INTERVALS	REMARKS
A	1569					2270					STADIA FACTOR
	1500	15003		069		1916	19150	-0.2	355		= 0.100
	1432			068		1560			355		
	4501	15003			137	5746	19150			710	
B	1728					1628					
	1671	16717		057		1260	12597	-0.4	368		
	1616			055	112	0891			369	737	
	9516	31720			249	9524	31747			1447	
							-0.7			249	
							31740			1198	
							31720				
		$\frac{-2.0}{1198}$	= -0.0017 = C				-2.0				

[illegible]

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READING THE HORIZONTAL PLATE
OF THE WILD T-2 THEODOLITE

INTRODUCTION

The measuring of a horizontal direction or angle is one of the basic jobs of any type of surveyor. There are many types of instruments that can be used to accomplish this task. At the present time, the Wild T-2 Theodolite is the basic direction measuring instrument used by the topographic surveyor.

To measure a horizontal direction, the surveyor must be able to determine the instrument readings. This programmed instruction booklet is designed to teach you how to read the horizontal scales of the Wild T-2 Theodolite.

OBJECTIVE OF THIS LESSON

Given a Wild T-2 Theodolite or a graphic representation of the image seen in the reading microscope, the student will read the horizontal scale of the Wild T-2 Theodolite with 100% accuracy.

898

READING THE HORIZONTAL PLATE OF THE WILD T-2 THEODOLITE

INSTRUCTIONS TO STUDENTS

1. This programmed lesson is designed to be used without an instructor. There is an instructor available to assist you with any questions you may have.

2. This programmed lesson gives you instruction at your own pace. Although some of the material may seem simple to you, DO NOT RUSH through it. You may review the items that you have previously studied as much as you like.

3. THIS IS NOT A TEST. It is a means of learning using a style of programming called "Linear Programming". In each frame there is a small bit of information. After reading the frame, you will be required to form a response. Think out the answer and write it in the space(s) provided. The correct answer will appear at the top of the next frame. If the answer you have written is correct, go on to the next frame. If your answer is incorrect, crossout the wrong answer, read the frame again, and write the correct answer beside the crossed out one. Then continue to the next frame. You are not graded on your answers, but you should write your answer before checking the correct answer.

4. Don't guess at any answer. You will be given the correct answer following each response.

5. You are now ready to begin. Turn to page 1, frame #1.

899

FRAME #1

To prepare the Wild T-2 Theodolite for horizontal plate reading, after it has been leveled and plumbed over a station, two steps must be taken. The first of which is to lock the cross hairs of the telescope on the target.

RESPONSE: The first step in preparing the T-2 for horizontal plate reading is to ________ the telescope ______________ on the target.

ANSWER: 9 (If your answer is incorrect, reread Frames 28 and 40.)

FRAME #43

The ending point, when counting the number of "tens of minute" gaps in our horizontal reading, is always an upside-down number in the top scale of the reading microscope window.

RESPONSE: When counting the number of "tens of minute" gaps in our horizontal reading, the ending point is always an ______________ ______________.

900

FRAME #2

ANSWER: Lock, cross hairs

The second step, after the cross hairs are locked on the target, is to turn the inverter knob (see picture, pg 46, this text) so that the black line is in the horizontal position.

RESPONSE: Turning the inverter knob so that the ________ ______ is in the horizontal position.

ANSWER: Upside down

FRAME #44

RESPONSE: In finding the ending point, when counting the number of "tens of minute" gaps to be used in the horizontal reading, you first look for a number which is ____________ ________.

952

FRAME #3

ANSWER: Black line

RESPONSE: The horizontal plate of the Wild T-2 is not ready for reading until the ______ _______ are locked on the target and the _________ _____ is turned so that the black line on it is ___________.

ANSWER: Upside down

FRAME #45

The upside down ending point number, which we must use, can be found in one of two places.

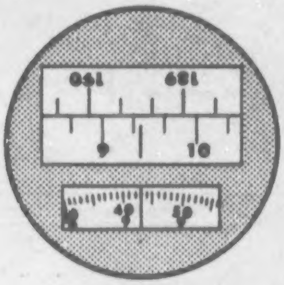
RESPONSE: When finding which of the upside down numbers to use as an ending point, when counting the "ten minute" gaps, we look in one of ____ ________.

902

FRAME #4

ANSWER: Cross hairs, inverter knob, horizontal

When the T-2 is prepared for horizontal plate reading, the first image seen in the reading microscope (see picture, Pg46 this text) window is similiar to that shown in the figure below.



RESPONSE: The figure above shows an image similiar to that first seen in the reading microscope window of the T-2 that is ____________ for horizontal plate reading.

ANSWER: Two places

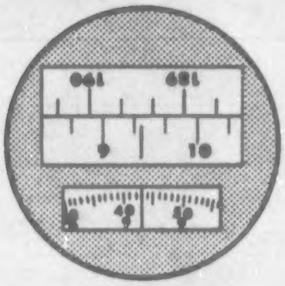
FRAME #46

The first place to look for the upside down number is directly over the index line in the top scale.

RESPONSE: When finding the upside number which is the ending point, when counting the number of "ten minute" gaps, you first look ______________ over the index line.

FRAME #5

ANSWER: Prepared

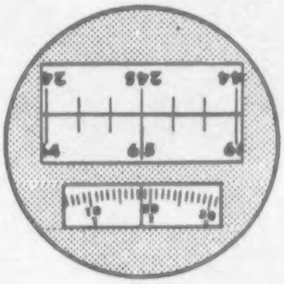


RESPONSE: When the image in the reading microscope is similiar to that shown in the figure above, you know that the Wild T-2 Theodolite has been prepared for ______________ ________ reading.

ANSWER: Directly

FRAME #47

In the figure below, you can see that there is an upside down number directly over the index line.

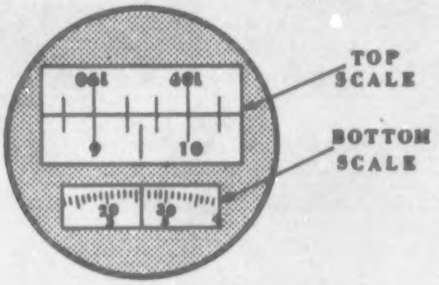


RESPONSE: The upside down number, which is the ending point when counting the number of "ten minute" gaps in the horizontal reading, is directly over the ________ _______ in the figure above.

FRAME #6

ANSWER: Horizontal plate

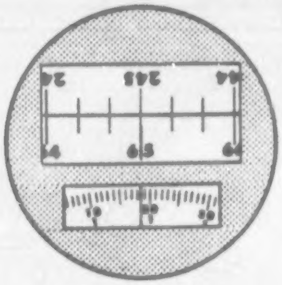
You may have noticed that the image seen in the reading microscope is divided into two scales. They will be referred to from here on as the top scale and the bottom scale. See figure below.



RESPONSE: In the figure above, you can see that the reading microscope image is divided into ____ scales.

ANSWER: Index line

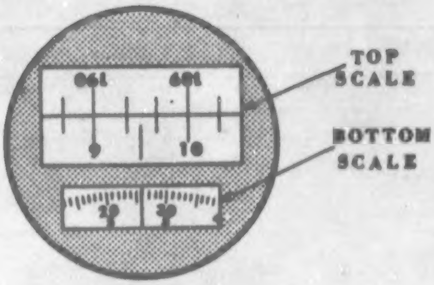
FRAME #48



RESPONSE: In the figure shown above, what number is the ending point when counting the number of "ten minute" gaps in the horizontal reading.

FRAME #7

ANSWER: Two

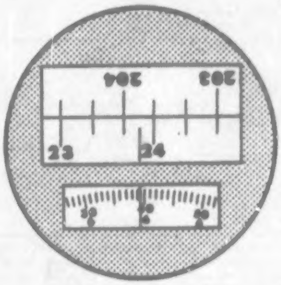


RESPONSE: There are two scales in the image window of the ________ ____________.

ANSWER: 245

FRAME #49

The second place to look for the upside number which marks the ending point, when counting the number of "ten minute" gaps in the horizontal reading, is the first upside down number to the RIGHT of the index line.



RESPONSE: In the figure above, there is no upside down number directly over the index line. Therefore you must look at the first upside down number to the __________ of the index line to find the ending point when counting the number of "ten minute" gaps in the horizontal reading.

FRAME #8

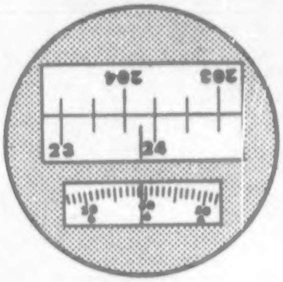
ANSWER: Reading microscope

The first of six steps in reading the horizontal plate of the Wild T-2 Theodolite is to bring the top scale into coincidence.

RESPONSE: Bringing the top scale into _____________ is the first step in reading the horizontal plate of the T-2.

ANSWER: Right

FRAME #50



RESPONSE: In the figure above, the ending point when counting the number of "ten minute" gaps is the first upside down number which is to the right of the _______ __ ____.

907

FRAME #9

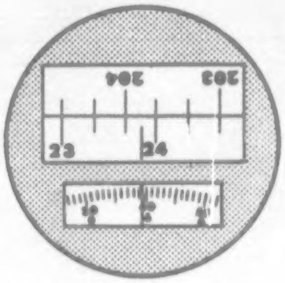
ANSWER: Coincidence

The horizontal plate cannot be read correctly if the top scale is not brought into coincidence.

RESPONSE: You will not get a correct reading of the _____________ _________ if the top scale is not brought into coincidence.

ANSWER: Index line

FRAME #51



RESPONSE: In the figure above, what number is the ending point when counting the number of "ten minute" gaps in the horizontal reading? ________.

959

ANSWER: Horizontal plate **FRAME #10**

The top scale is in coincidence when the vertical lines of the upper half of the top scale all line up with the vertical lines in the lower half of the top scale. See figures 1 and 2 below.

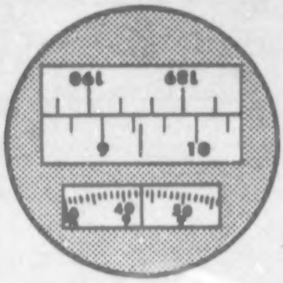


FIGURE 1

NOT IN COINCIDENCE

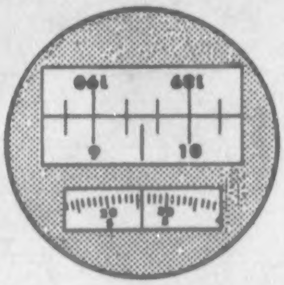
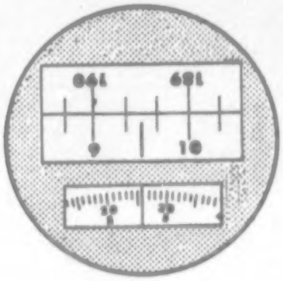


FIGURE 2

IN COINCIDENCE

RESPONSE: When the vertical lines in the upper and lower halves of the top scale are __________ ____, the scale is said to be in coincidence.

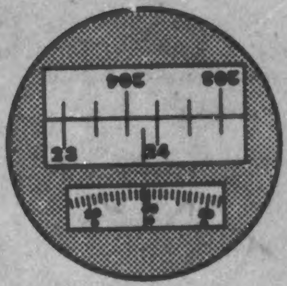
ANSWER: 203 **FRAME #52**



rRESPONSE: In the figure above, select the ending point number you would use in counting the number of "ten minute" gaps in your horizontal reading. ______

FRAME #11

ANSWER: Lined up



RESPONSE: In the figure above, a correct horizontal plate reading can cannot be made, because the top scale is is not in coincidence.
(cross out one) (cross out one)

ANSWER: 189

FRAME #53

The are two checks you can make on the ending point upside down number selected to ensure that it is the correct number.

RESPONSE: The ending point upside down number can be checked in ______ ways.

FRAME #12

ANSWER: Can is

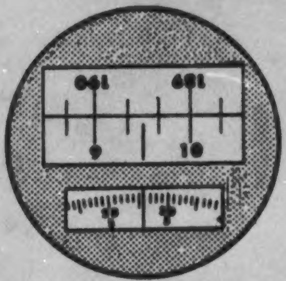
To bring the top scale into coinciience, the micrometer knob (see picture, pg 46, this text) is used.

RESPONSE: The ___________ _____ is used to bring the top scale into coinciience.

ANSWER: Two

FRAME #54

The first check is to ensure that the last digit of the ending point upside down number, AGREES with the last diget of the degree reading.



RESPONSE: In the figure above, there are three gaps of "tens of minutes" in the horizontal reading and that the last digits of the degree reading and the upside down number ending point ___________.

FRAME #13

ANSWER: Micrometer knob

The top scale is brought into coincidence by turning the micrometer knob (sometimes called the coincidence knob) until the image in the reading microscope changes from one similiar to that shown in figure 1, to one similiar to that shown in figure 2 below.

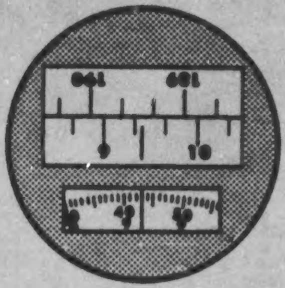


Figure 1

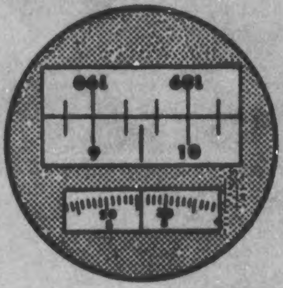


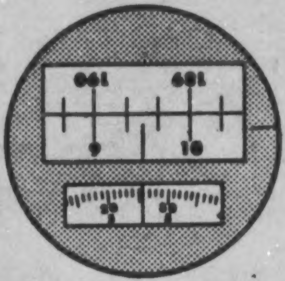
Figure 2

RESPONSE: The micrometer knob is ______ until the reading microscope image is similiar to that shown in Figure ___ above.

ANSWER: Agree

FRAME #55

An alternate check is to insure that the degree reading and the ending point number selected are 180 degrees apart. See figure below.



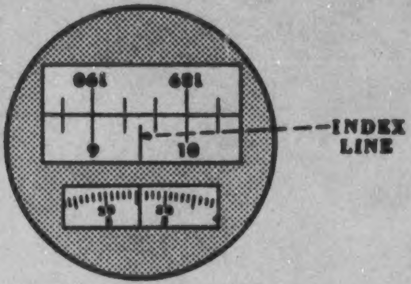
RESPONSE: A second check, that can be made to ensure that you have selected the right ending point number, is to ensure that the degree reading and the ending point number are _____ degrees apart.

912

FRAME #14

ANSWER: Turned, 2

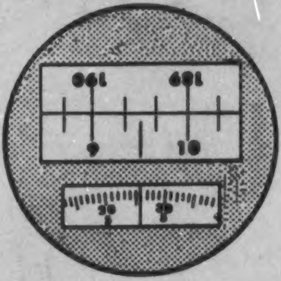
The second of the six steps in reading the horizontal scales of the Wild T-2 Theodolite is to locate the INDEX LINE in the top scale of the reading microscope window, after the scale is in coincidence.



RESPONSE: Once the top scale is brought into coincidence, you must look in the top scale for the ________ line.

ANSWER: 180

FRAME #56

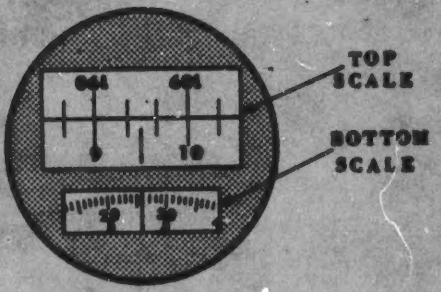


RESPONSE: In the figure above you can see that there are three "ten minute" gaps in the horizontal reading and that the degree reading and the ending point number are ______ degrees __________.

954

FRAME #15

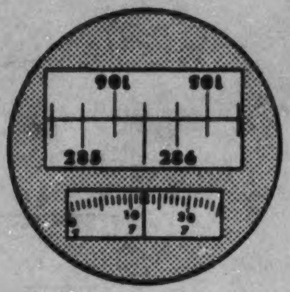
ANSWER: Index


TOP SCALE
BOTTOM SCALE
9
10
20
30

RESPONSE: In the figure above, the index line can be found in the ______ scale of the reading microscope window.

ANSWER: 180, apart

FRAME #57

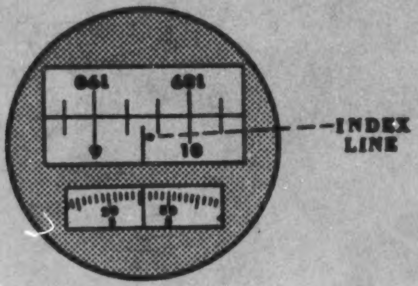

285
286
10
20

RESPONSE: How many gaps of "ten minutes" each are there in the horizontal reading in the figure above.

FRAME #16

ANSWER: Top

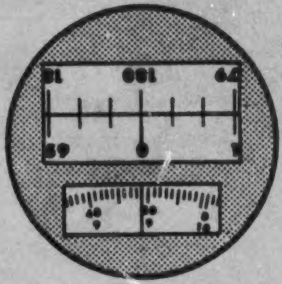
The index line is located in the CENTER of the BOTTOM half of the top scale as shown in the figure below.



RESPONSE: In the figure above, you can see that the index line is located in the center of the ____________ half of the top scale.

ANSWER: 4

FRAME #58



RESPONSE: In the figure above, how many gaps of "ten minutes" each will you use in your horizontal scale reading? _______

FRAME #17

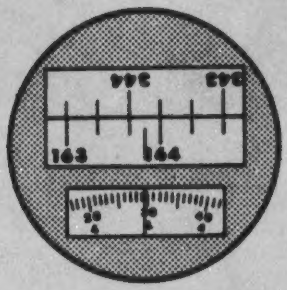
ANSWER: Bottom

The index line in the top scale is NOT used directly to obtain a reading.

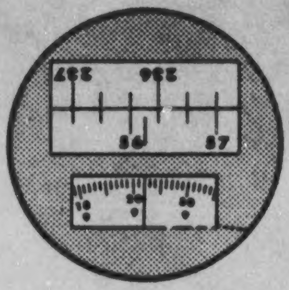
RESPONSE: When reading the top scale, seen in the reading microscope window, the index line is ______ directly used to obtain the reading.

ANSWER: None or 0

FRAME #59


344
343
163
164
20
30
40

a.


237
236
56
57
10
20
30

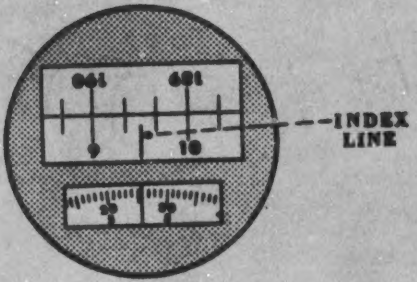
b.

RESPONSE: The top scale, in the figures above, give what degree and minute readings? a. ____________ b. __________

916

FRAME #18

ANSWER: Not



RESPONSE: In reading the top scale in the reading microscope window, as shown in the figure above, you do not use the ___________ ________ directly to obtain a reading.

ANSWER: a. 163° 50'
b. 56° 10'

FRAME #60

You have now completed four of the six steps in the reading of the horizontal scale of the Wild T-2 Theodolite.

RESPONSE: The first four steps in reading the horizontal scale of the Wild T-2 Theodolite are

1. Bring the ____ ________ into coincidence.
2. ___________ the index line.
3. Determine the ________ reading.
4. Read the ______ of ___________.

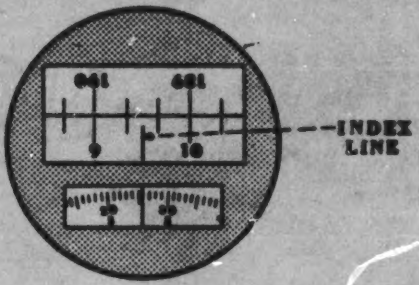
988

917

FRAME #19

ANSWER: Index line

The purpose of the index line, in the top scale, is to mark the center of the field of view. You could actually say that it is a reference line.



RESPONSE: The index line, shown in the figure above, aids in finding the __________ of the field of view.

ANSWER:
1. Top scale
2. Locate
3. Degree
4. Tens minutes

FRAME #61

The FIFTH step in reading the horizontal scales is to read the UNIT MINUTES (0 thru 9).

RESPONSE: When reading the horizontal scales, the fifth step is to read the ______ minutes.

989

FRAME #20

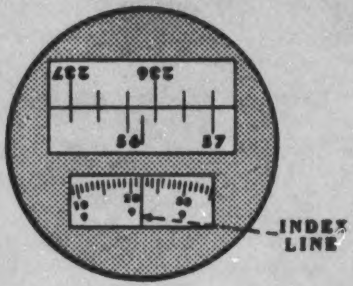
ANSWER: Center

RESPONSE: You find the center of the field of view of the top scale by locating the __________ _______.

ANSWER: Unit

FRAME #62

Looking at the bottom scale of the reading microscope window, as shown in the figure below, you will notice an index line in the center of the scale.



RESPONSE: The long line in the center of the bottom scale is an __________ ________.

FRAME #21

ANSWER: Index line

SELF TEST

1. The first step in reading the horizontal scales of the T-2 is to bring the top scale into _____________. (See Frame #8)
2. The index line is used to determine the __________ of the field of view of the top scale in the reading microscope window, (see Frame #19)
3. The index line is _____ used directly to obtain a reading in the top scale in the reading microscope window. (See Frame #17)
4. The second step in reading the horizontal scales of the T-2 is to locate the ________ _______ in the top scale of the reading microscope window. (See Frame #14)

ANSWER: Index line

FRAME #63

The unit minutes (0 thru 9) are found in the BOTTOM SCALE of the reading microscope window.

RESPONSE: To read the unit minutes, of the horizontal reading, you must look in the ___________ scale of the reading microscope window.

920

FRAME #22

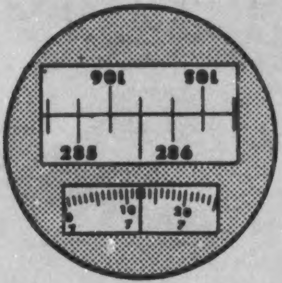
ANSWERS TO SELF TEST:
1. Coincidence
2. Center or middle
3. Not
4. Index line

The third step in reading the Wild T-2 Theodolite horizontal scales is to locate the DEGREE reading in the top scale of the reading microscope window.

RESPONSE: You will find the _______ reading in the top scale of the reading microscope window.

ANSWER: Bottom

FRAME #64

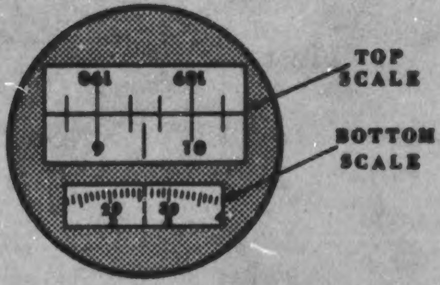


RESPONSE: In the bottom scale, of the figure shown above, can be found the _______ __________ of the horizontal reading.

921

FRAME #23

ANSWER: Degree

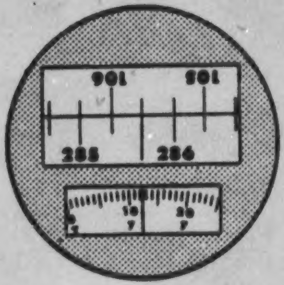


RESPONSE: To locate the degree reading you must look in the _____ scale of the reading microscope window.

ANSWER: Unit minutes

FRAME #65

In the bottom scale of the reading microscope window, as shown in figure below, you will notice pairs of numbers, consisting of a top number and a bottom number.



RESPONSE: In the figure above, you can see that $\begin{matrix}20\\7\end{matrix}$ forms a _____ of numbers in the bottom scale.

973

FRAME #24

ANSWER: Top

In the top scale, the degree reading can be found at one of two places.

RESPONSE: You can find the degree reading in the top scale at ____ of ______ places.

ANSWER: Pair

FRAME #66

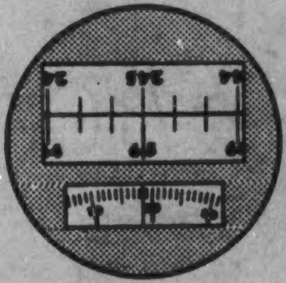
The unit minute reading from this scale is always the BOTTOM number.

RESPONSE: When reading the unit minutes (0 thru 9), from the bottom scale in the reading microscope window, you always read the ____________ number.

ANSWER: One, two

FRAME #25

The first place to look for the degree reading, in the top scale, is DIRECTLY ON the index line.



RESPONSE: In the figure above, there are two degree readings

D________ O___ the index line.

ANSWER: Bottom

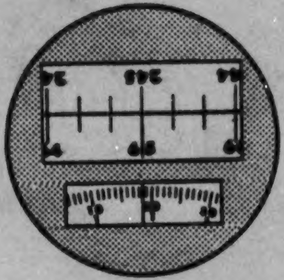
FRAME #67

The bottom number, selected as the unit minute reading can be in one of two places.

RESPONSE: In selecting the unit minute reading, from the bottom scale of the reading microscope window, you will look in one of _____ places.

ANSWER: Directly on **FRAME #26**

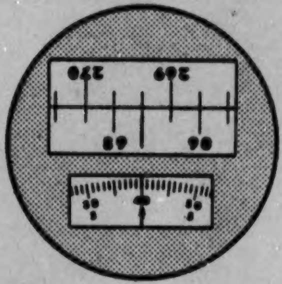
The RIGHT-SIDE-UP number, directly on the index line is the DEGREE READING used.



RESPONSE: In the figure above, the right-side-up number directly on the index line is the ____________ __________ you use.

ANSWER: Two **FRAME #68**

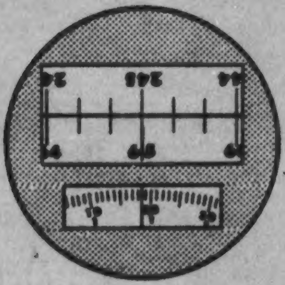
The first place to look for the bottom number, which indicates the unit minutes, is directly under the index line. See figure below.



RESPONSE: In selecting the bottom number, which will give you the unit minute horizontal scale reading, you will first look directly under the ________ _________.

925

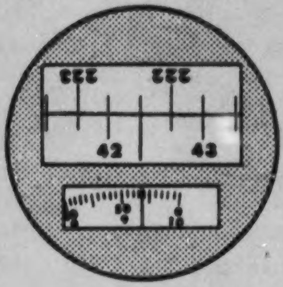
ANSWER: Degree reading **FRAME #27**



RESPONSE: In the figure shown above, the degree reading would be __________.

ANSWER: Index line **FRAME #69**

The second place to look for the unit minutes of the horizontal reading is the first number to the LEFT of the index line, as shown in the figure below.



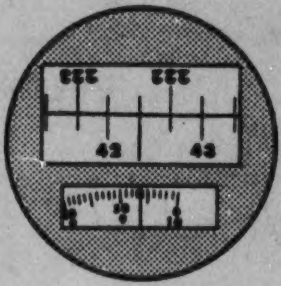
RESPONSE: In selecting the bottom number, which will give you the unit minute reading of the horizontal plate, the second place to look is the first number to the ________ of the index line.

977

926

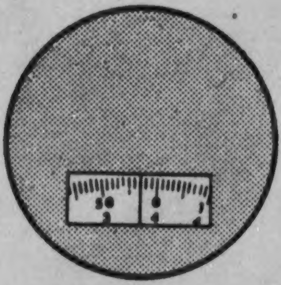
ANSWER: 65 **FRAME #28**

The second place to look for the degree reading is the first right-side-up number to the LEFT of the index line in the top scale.

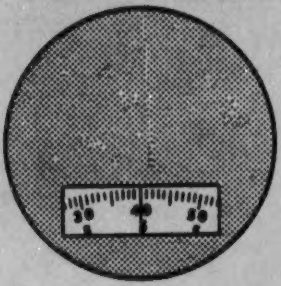


RESPONSE: The degree reading, in the figure above, is the first right-side-up number to the ________ of the index line in the top scale.

ANSWER: Left **FRAME #70**



a.



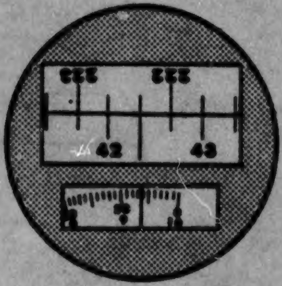
b.

RESPONSE: What are the unit minutes of the horizontal scales in the figures shown above? a. ________ b. ________

978

ANSWER: Left

FRAME #29



RESPONSE: In the figure above there is no number directly on the index line. Therefore the first number to the left of the index line is the __________ __________.

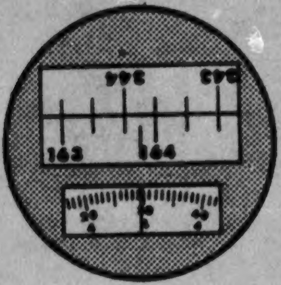
ANSWER: a. 3, b. 5

FRAME #71

The unit minutes are ADDED to the "tens of minutes", read from the top scale in the reading microscope, to give you the total minute reading of the horizontal scale.

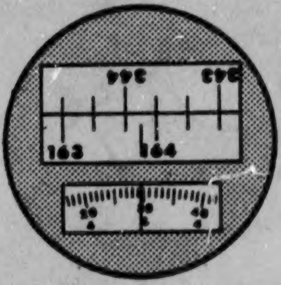
RESPONSE: To arrive at a total minute reading, for the horizontal scales, the "tens of minutes" reading and the unit minute reading are __________.

ANSWER: Degree reading **FRAME #30**

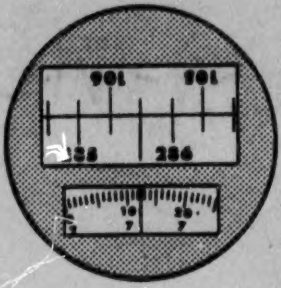

344
343
163
164
20
30
40

RESPONSE: The figure above shows a degree reading of _________.

ANSWER: Added **FRAME #72**


344
343
163
164
20
30
40

a



b

RESPONSE: What are the total minute readings for the figures shown above? a. _________ b. ________

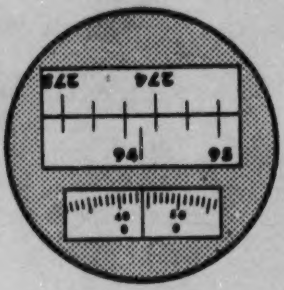
ANSWER: 163

FRAME #31

RESPONSE: After locating the index line, you next look for the degree reading directly on the ______ ______. If no number appears there, you next look for the first right-side-up number to the ______ of the index line.

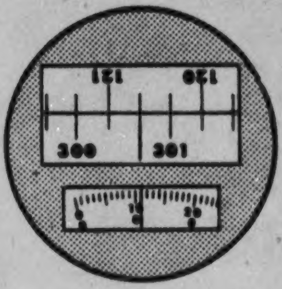
ANSWER: a. 54, b. 47

FRAME #73



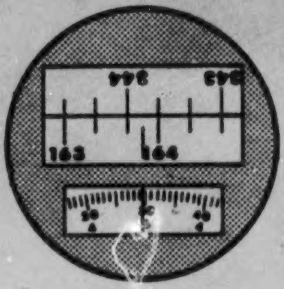
274
273
94
95
40
0
50
0

a



121
120
300
301
0
10
20

b



344
343
163
164
30
40

c

RESPONSE: What are the horizontal scale readings, in degrees and and minutes, in the figures shown above?

a. ______

b. ______

c. ______

930

ANSWER: Index line, left **FRAME #32**

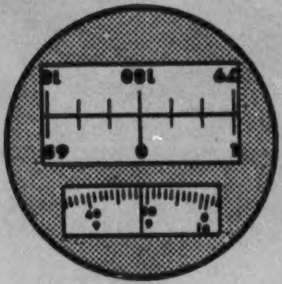


Figure 1

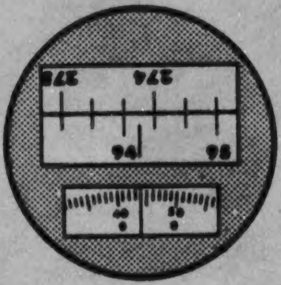


Figure 2

RESPONSE: In figure 1 above, the degree reading is __________.

In figure 2 above, the degree reading is __________.

ANSWER: a. 94° 10, b. 300° 40', c. 163° 54' **FRAME #74**

You have now completed the first five of the six steps used to determine the reading of the Wild T-2 Theodolite horizontal scales. These steps are:

1. Bring the top scale into ____________,
2. Locate the _________ _________,
3. Read the ___________,
4. Read the ______ of ______________, and
5. Determine the ________ _____________.

932

931

ANSWER: Fig. 1 - 0°, Fig. 2 - 94 **FRAME #33**

RESPONSE: The first three steps in reading the horizontal plate of the Wild T-2 Theodolite are:

1. Bring the plate into ___________.
2. Locate the _______ _______.
3. Locate the __________ __________.

ANSWER: **FRAME #75**

1. Coincidence
2. Index line
3. Degrees
4. Tens, minutes
5. Unit minutes

The SIXTH and final step, in reading the horizontal plates of the Wild T-2 Theodolite, is to read the seconds.

RESPONSE: When reading the horizontal scales of the Wild T-2 Theodolite, the final step is to read the _____________.

932

ANSWER: 1. Coincidence
2. Index line
3. Degree reading

FRAME #34

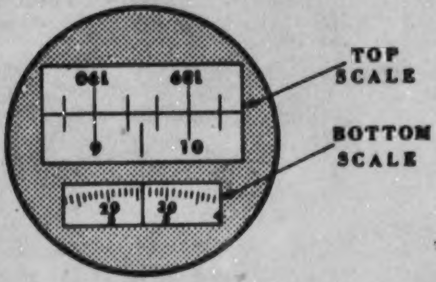
The FOURTH step in reading the horizontal scale is to find the number of "tens of minutes" in the top scale of the reading microscope window.

RESPONSE: Finding the number of _______ ___ _______________ in the top scale is the fourth step in reading the horizontal scales of the Wild T-2.

ANSWER: Seconds

FRAME #76

The "seconds" reading is found in the bottom scale of the reading microscope window.

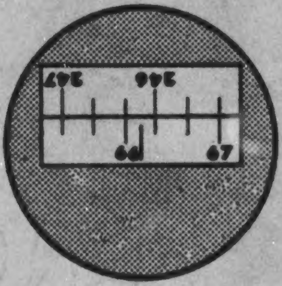


RESPONSE: In the figure above, you can find the "seconds" reading of the horizontal plates in the __________ scale of the reading microscope window.

934

ANSWER: Tens of minutes **FRAME #35**

It is possible that you have noticed that the numbers in the upper half of the top scale are upside-down.



RESPONSE: In the figure above you can see that the numbers in the upper half of the top scale are _________ ________.

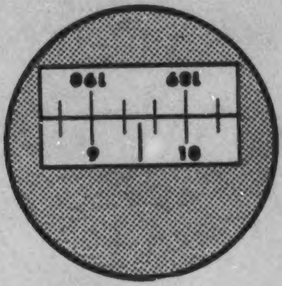
ANSWER: Bottom **FRAME #77**

To find the correct "seconds" reading in the bottom scale, you first must locate the index line.

RESPONSE: When reading "seconds", from the bottom scale, the index line is located ___________.

ANSWER: Upside down **FRAME #36**

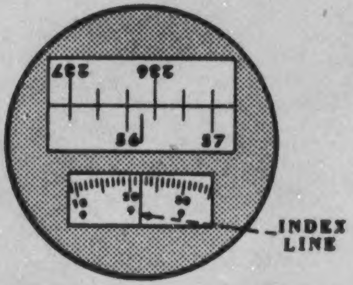
You may have also noticed that when the T-2 is prepared for horizontal plate reading, the top scale is divided into a series of equal gaps or spaces by the scale (vertical) lines.



RESPONSE: In the figure above, you can see that the top scale is divided into a series of equal ________.

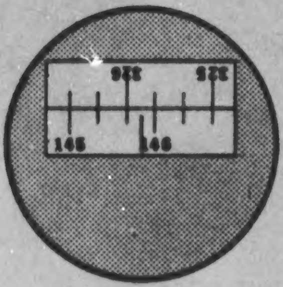
ANSWER: First **FRAME #78**

After the index line is located, you read the "seconds" directly at the index line of the bottom scale.



RESPONSE: At the index line of the bottom scale, you directly read the ______________.

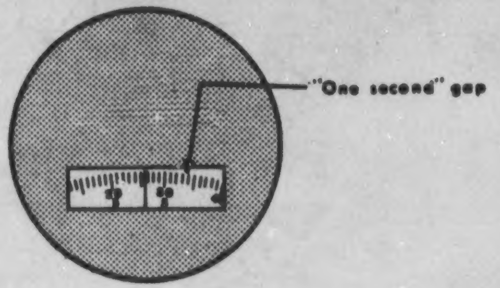
ANSWER: Gaps or spaces **FRAME #37**



RESPONSE: When a Wild T-2 Theodolite is prepared for horizontal plate reading, the top scale seen in the reading microscope is divided by the scale lines into gaps which are __________, as shown in the figure above.

ANSWER: Seconds **FRAME #79**

Each small gap in the bottom scale is equal to ONE second.



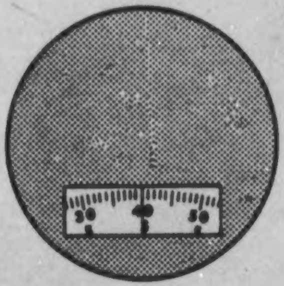
RESPONSE: In the figure above each of the small gaps is equal to ______ second.

ANSWER: Equal **FRAME #38**

When reading the top scale, each one of the gaps or spaces we use is equal to ten minutes.

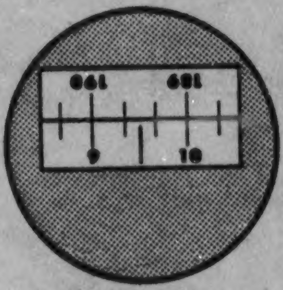
RESPONSE: Each of the gaps or spaces you use in reading the top scale is equal to ______ ________________.

ANSWER: One **FRAME #80**



RESPONSE: The gaps in the second scale are equal to ___ ________ each.

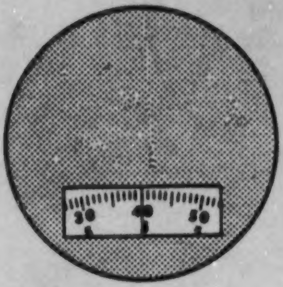
ANSWER: Ten minutes **FRAME #39**



RESPONSE: In the figure above, each of the gaps you count in your horizontal plate reading will be counted as one gap equals ____ ______________.

ANSWER: One second **FRAME #81**

Each ten gaps, on the second scale, are numbered. The top number of the pairs of numbers, is the "tens of seconds" reading.



RESPONSE: In the figure shown above, each ten small gaps are ______________ and the "tens of seconds" number is the ______ number.

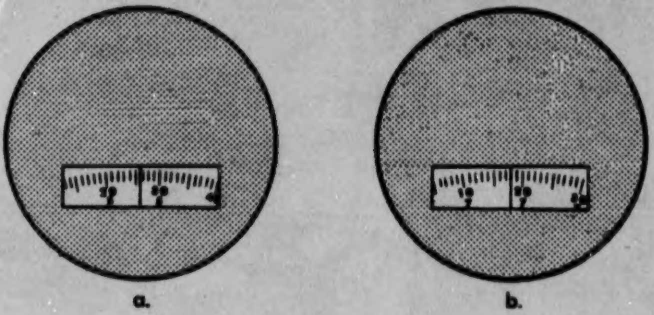
938

ANSWER: Ten minutes **FRAME #40**

The DEGREE READING is the STARTING point used to begin counting the number of "tens of minute" gaps in the horizontal reading.

RESPONSE: The starting point we use to begin counting the number of "tens of minute" gaps in our horizontal reading is the __________ ______________.

ANSWER: Numbered, top **FRAME #82**



a. b.

RESPONSE: What are the seconds reading in the figures shown above?

a. __________ b. ____________

990

ANSWER: Degree reading **FRAME #41**

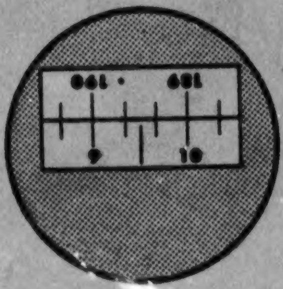
RESPONSE: To arrive at the number of "tens of minute" gaps we should count in our horizontal reading, we use the degree reading as a ____________ ________.

ANSWER: a. 26", b. 18" **FRAME #83**

You have now completed the sixth and final step in reading the scales of a Wild T-2 Theodolite. The

1. Bring the ________________________,
2. Locate the ________________________,
3. Read the ________________________,
4. Read the ________________________,
5. Read the ________________________,
6. Read the ________________________.

ANSWER: Start point. **FRAME #42**

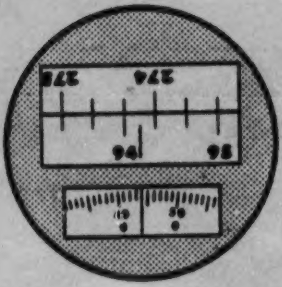


RESPONSE: In the figure shown above, what number should we use as the starting point for counting the number of "tens of minute" gaps in our horizontal reading.

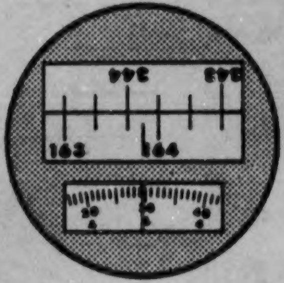
TURN TO FRAME #43, PAGE 1, FOR ANSWER TO FRAME #42.

ANSWER:
1. Top scale into coincidence.
2. Index line
3. Degrees
4. Tens of minutes
5. Unit minutes
6. Seconds

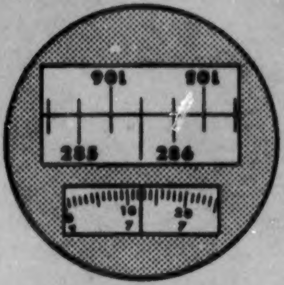
FRAME # 84


273
274
94
95

a.


344
343
163
164

b.


106
105
285
286

c.

RESPONSE: What are the horizontal plate readings, in degrees, min minutes and seconds, of the figures shown above?

a. ______________ b. ______________ c. ____________

ANSWER: a. 94 10' 44"
b. 163° 54' 29" or 30"
c. 285° 47' 12" or 13"

SELF TEST

These self-test questions are provided to give you practice in using the information that you learned from your study of this text. The answers to each question are on page 45. You should be able to answer all questions correctly, but if you miss any, reread the frame or frames noted on the answer sheet .

1. What readings are obtained from the top scale of the reading microscope window?

   ____________________ ________________________________

2. What readings are obtained from the bottom scale of the reading microscope window?

   ______________________________ ____________________

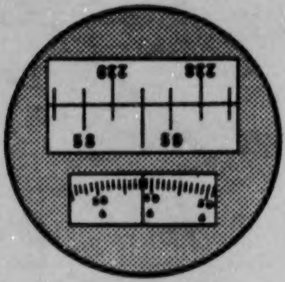
3. What is used to find the center of the field of view in the top scale of the reading microscope window?

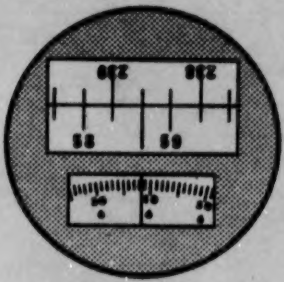
   ____

4. Is the index line, in the bottom scale of the reading microscope window, used as a direct mark for reading seconds? _____

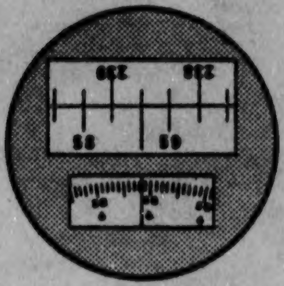
5. In the figure below, the correct degree reading is __________________.

6. In the figure below, the correct number of "tens of minutes" gaps is _____.

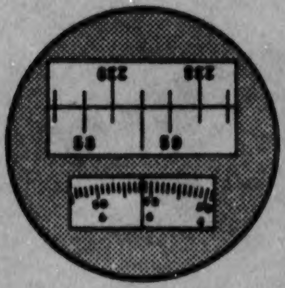




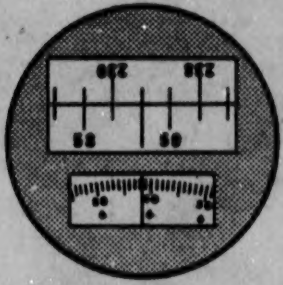
7. In the figure below, the correct unit minute reading is ________.



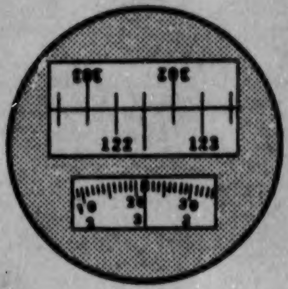
8. In the figure below, the correct total minute reading is ________.



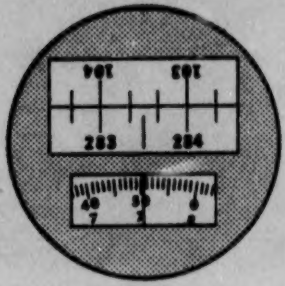
9. In the figure below, the correct seconds reading is ________.



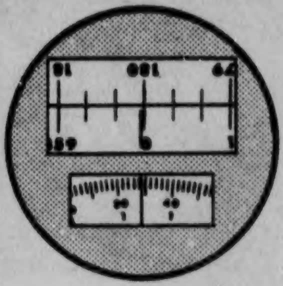
10. In the figure below, the correct horizontal scale reading is ____________.



11. In the figure below, the correct horizontal scale reading is _____________.



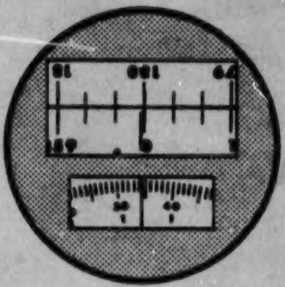
12. In the figure below, the correct horizontal scale reading is ______________.



ANSWERS TO SELF TEST

1. Degrees and "tens of minutes". See Frames #22 & 34.
2. Unit minutes and seconds
3. Index line. See Frame #19.
4. Yes. See Frame #78
5. 58 . See Frame #28
6. 4. See Frames #40 thru 43.
7. 06'. See Frames #66 thru 69.
8. 46'. See Frame #71.
9. 38". See Frames #78 thru 81.
10. 122° 23' 22"
11. 283° 37' 50"
12. 00° 01' 34".....This one may have seemed a little tricky. It will occur if the index line, in the top scale, does not mark the exact center of the field of view. (Frame #19)

Don't let it throw you as all the rules still apply. Find the right-side-up number to the left of the index line (Frame #28). In the figure below left, it is 359 . This is your DEGREE reading.



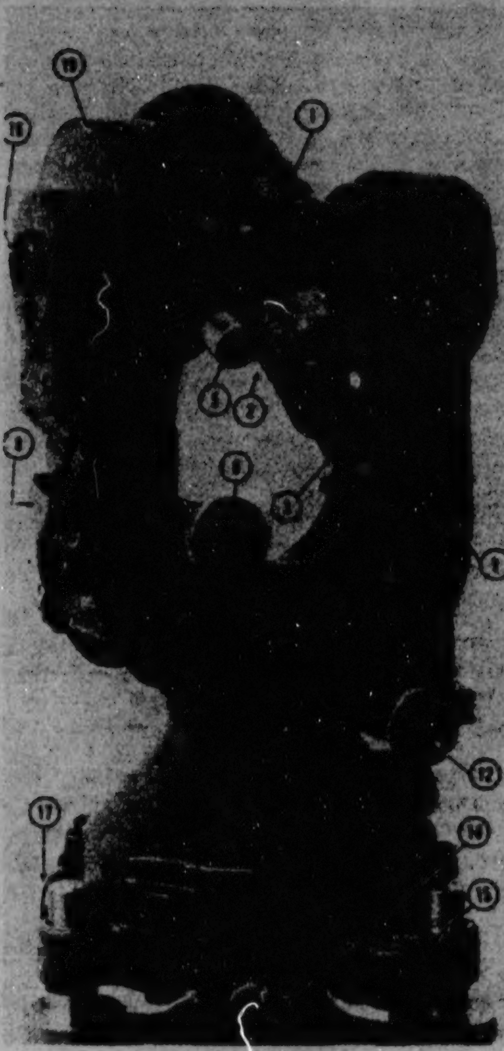
Next, find the up-side-down number to the right of the index line. This is the end point for counting "tens of minutes"(Frame #49). In the figure to the left, it is 179 . Although you you can't see the 1 of the 179, you know it's there.

Next, count the number of "tens of minute" gaps from the start point, 359, to the end point 179 (Frame #43 and 49). In the figure above left, there are 6 gaps of "tens of minutes" or 60'.

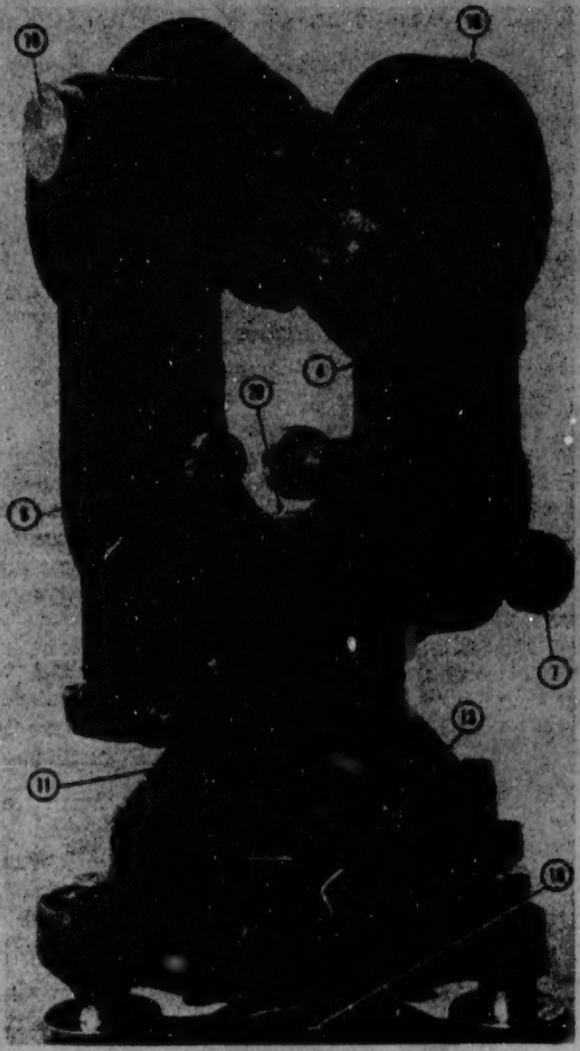
Therefore the degrees and "tens of minutes could be written as 359° 60', but for clarity it is recorded as 00° 00'.

The unit minutes and seconds are found as shown in Frames #66, 69, 78, 79, 80 & 81.

WILD T-2 THEODOLITE



(1) CIRCLE LEFT

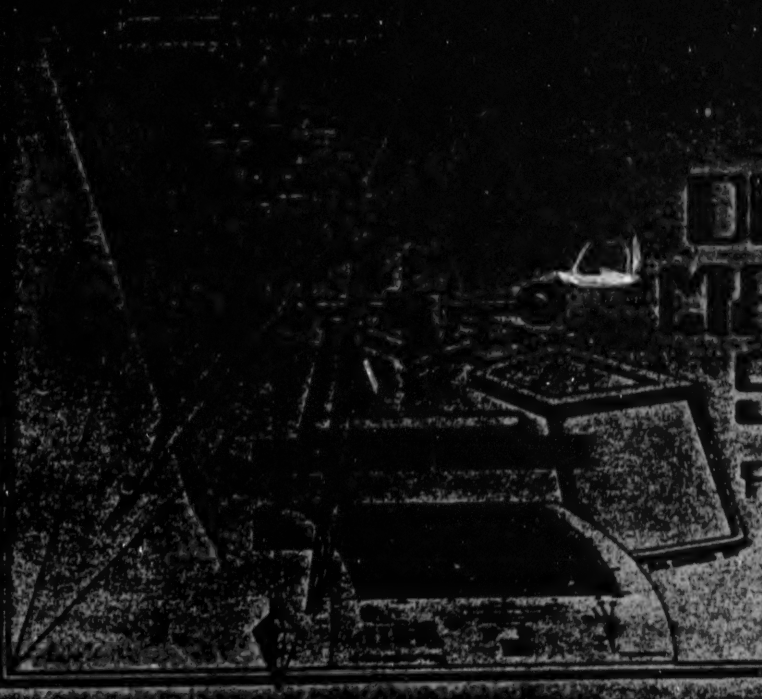


(2) CIRCLE RIGHT

1 Diaphragm illuminating knob
2 Focusing ring
3 Telescope eyepiece
4 Microscope eyepiece
5 Telescope clamp
6 Vertical slow-motion screw
7 Collimation slow-motion screw
8 Collimation level
9 Inverter knob
10 Micrometer knob
11 Horizontal clamp knob
12 Horizontal slow-motion screw
13 Horizontal drive cover
14 Optical plumb eyepiece
15 Circular level
16 Vertical circle illumination
17 Horizontal circle illumination
18 Tribrach locking handle
19 Vertical circle housing
20 Plate level

[illegible]

[illegible]



DEFENSE MAPPING SCHOOL

FORT BELVOIR
VIRGINIA

MAY 1978

946

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Instructions to Students iii

Lesson Frames 1-28

COMPUTATION OF STRENGTH OF FIGURE

INTRODUCTION

Another important task of the triangulation reconnaissance party is the determination of the "Strength of Figure" of all triangulation figures within a triangulation scheme.

The total "Strength of Figure" must be known by the reconnaissance party so that they will know where and when to establish new measured baselines within the chain of triangulation figures.

OBJECTIVE OF THIS LESSON

Given the size of all angles, in a triangulation figure, and Table 4-1, TM 5-441, the student will compute the "Strength of Figure" for each route of computation through the triangulation figure with 100% accuracy.

INSTRUCTIONS TO STUDENTS

1. This programmed lesson is designed to be used without an instructor. However, if you have any questions, an instructor will be available to answer them.

2. This programmed lesson allows you to proceed at your own pace. Although some of the material may seem simple to you, DO NOT RUSH through it. You may review the items that you have previously studied as much as you like.

3. THIS IS NOT A TEST. It is a means of learning, using a style called "Linear Programming." In each frame, you will be required to form a response. Think out the answer and WRITE it in the space(s) provided. The correct answer will appear on the next page. If the answer you have written is correct, go on to the next frame. If your answer is incorrect, cross out the wrong answer, read the frame again, and write the correct answer beside the incorrect one. Then continue to the next frame. You are not graded on your answers, but you should WRITE your answers before checking the correct answer.

4. DO NOT GUESS AT ANY ANSWER. You will be given the correct answer following each response.

5. You are now ready to begin. TURN TO PAGE 1, FRAME 1.

949

FRAME #1

In conventional triangulation, an important requirement for the reconnaissance party is the determination of the STRENGTH OF FIGURE, usually expressed as "R". The STRENGTH OF FIGURE is dependent upon directions observed, geometric conditions to be satisfied and the size of the angles.

RESPONSE: An important requirement for the conventional triangulation reconnaissance party is the determination of the ____________ ___ ____________.

ANSWER FRAME #28: Each Triangle

FRAME #29

When determining the polynomial ($\delta A^2 + \delta A \delta B + \delta B^2$), the values of δA and δB can be determined from a book of logarithms. To eliminate this task, Table 4-1, page 4-8, TM 5-441 will give the value for the polynomial directly using the DISTANCE ANGLES as arguments.

RESPONSE: The value for the polynomial can be determined by using Table 4-1 in TM 5-441. The ____________ ____________ are used as the arguments.

1001

ANSWER FRAME #1: Strength of Figure **FRAME #2**

The "Strength of Figure" is not based on an absolute scale, but rather is an expression of RELATIVE STRENGTH. The formula for determining the strength of figure (expressed as R) is:

$$R = \frac{D - C}{D} \sum (\delta A^2 + \delta A \delta B + \delta B^2)$$

D = the number of new directions observed in the figure

C = the number of conditions (angle and side) to be satisfied

δA and δB = respective logarithmic differences of the sines, expressed in units of the sixth decimal place, for 1 second in the distance angles A and B of a triangle

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ANSWER FRAME #29: Distance Angles **FRAME #30**

When using Table 4-1, the DISTANCE ANGLES are used as arguments for entering the table. The SMALLER distance angle is always the top argument and the LARGER distance angle is the side argument.

RESPONSE: The top argument is always the SMALLER distance angle and the ______________ distance angle is the side argument, when using Table 4-1.

951

FRAME #3

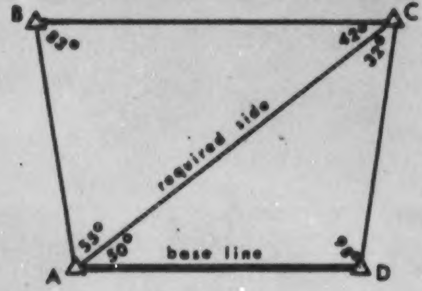
As you know from the law of sines, one method to compute the length of an unknown side of a triangle is by using two of its known angles and a known side. The two angles used are called the DISTANCE ANGLES.

RESPONSE: The TWO angles used to compute the length of an unknown side of a triangle are called the ____________ ____________.

ANSWER FRAME #30: Larger

FRAME #31

To determine the value for the polynomial ($\delta A^2 + \delta A \delta B + \delta B^2$) for the triangle ACD, in the figure below, you must determine what the distance angles are. The required side is line AC and the known side is the baseline AD. If you have forgotten what distance angles are, review Frames 3,4 and 5.

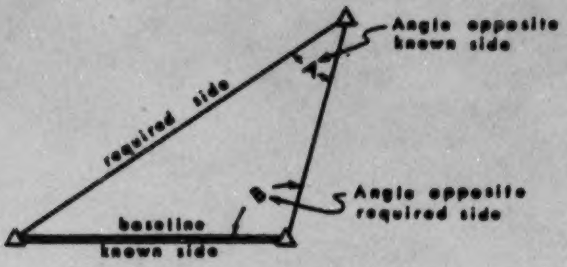


RESPONSE: The distance angles are ________ and ________.

1003

ANSWER FRAME #3: Distance Angles **FRAME #4**

The DISTANCE ANGLES are defined as: the angle opposite the KNOWN side and the angle opposite the REQUIRED side.

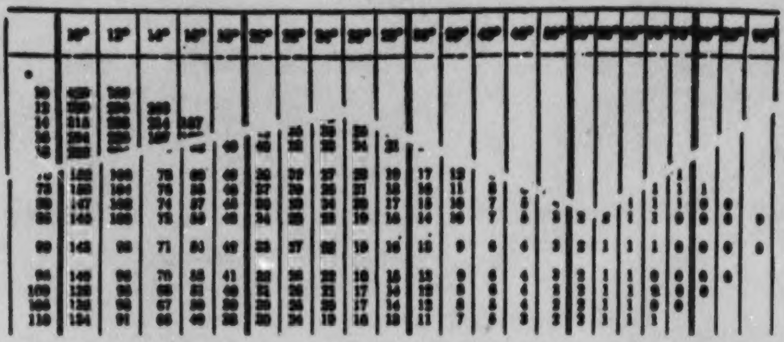

Angle opposite known side
A
required side
B
Angle opposite required side
baseline
known side

RESPONSE: The angle opposite the KNOWN side and the angle opposite the REQUIRED side are called the ____________ ____________.

ANSWER FRAME #31: 32°, 98° **FRAME #32**

Now that you have determined the distance angles, it is time to use Table 4-1, part of which is shown below. Enter the table with the SMALLER distance angle at the top and the LARGER one at the left side.

TABLE 4-1



RESPONSE: Using the distance angles for triangle ACD that you determined in Frame #31, you must enter the top of the table with ______° and the left side of the table with ______°

ANSWER FRAME #4: Distance angles **FRAME #5**

RESPONSE: The DISTANCE ANGLES are the angle opposite the ________________ side and the angle opposite the ________________ side.

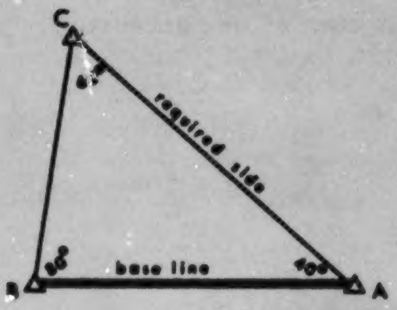
ANSWER FRAME #32: 32°, 98° **FRAME #33**

As you must have noticed, you cannot go directly into the Table with 32° and 98°, as there are no columns headed by these numbers. You are now going to have to INTERPOLATE to find the values needed.

RESPONSE: If your exact distance angles are not listed in Table 4-1, you will have to ________________ to find the values needed.

ANSWER FRAME #5: Known, Required **FRAME #6**

In the figure below, the known side is the baseline AB. The required side is the line AC.



RESPONSE: The distance angles are ______° and ______°.

ANSWER FRAME #33: Interpolate **FRAME #34**

The first step, in the interpolation, is to determine where your distance angles fall within the table. That is, between which two angles does your distance angle lie? Pull the copy of Table 4-1 from the back of this programmed lesson for use with the rest of the lesson.

RESPONSE: 1. 32° lies between ____° and ____° on top of Table 4-1.
2. 98° lies between ____° and ____° on the side of Table 4-1.

ANSWER FRAME #6: 60°, 80° **FRAME #7**

In the formula for determining the "Strength of Figure", $R = \frac{D-C}{D} \sum(\delta A^2 + \delta A \delta B + \delta B^2)$ you will learn to determine the value for D, then for C and then for the polynomial $(\delta A^2 + \delta A \delta B + \delta B^2)$

DETERMINATION OF "D"

The value of D (number of new directions) is equal to the TOTAL number of directions observed in the figure minus the number of directions observed over the BASE LINE (known line).

RESPONSE: D is equal to the __________ number of directions observed in the figure minus the number of directions observed over the __________ __________.

ANSWER FRAME #34: 1. 30°, 35°
2. 95°, 100° **FRAME #35**

Now that you know that 32° lies between 30° and 35° and that 98° lies between 95° and 100°, you can begin to INTERPOLATE. One way is to set yourself up a small table, such as the one shown below. Find 30° at the top of TABLE 4-1; go down the column until you are opposite 95° in the left column and record the number in your table below. Then continue down to 100° and record that number.

	30°		35°
95°			
100°			

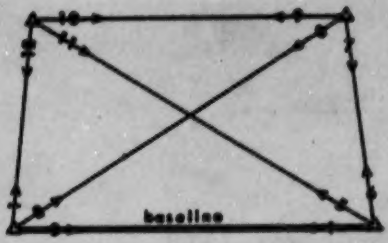
RESPONSE: 1. The number at the intersection of 30° and 95° is ________.

2. The number at the intersection of 30° and 100° is ________.

956

ANSWER FRAME #7: Total, Base line **FRAME #8**

To determine "D", first count all the directions observed in the figure. In the figure shown below, there are 12. Now count the number of directions observed over the base line. In the figure shown below there are two, the directions labled 3 and 4. The number of directions observed in the figure (12), minus the number of directions observed over the base line (2), equals the number of new directions observed (10) which is "D".



GO ON TO FRAME #9

ANSWER FRAME #35: 1. 13
2. 12

FRAME #36

Now repeat the process in Frame #35 only go down the column headed 35°.

	30°		35°
95°	12		
100°	12		

RESPONSE: 1. The number at the intersection of 35° and 95° is _______.
2. The number at the intersection of 35° and 100° is _______.

1008

FRAME #9

Determine "D" for the figures shown below. Solid lines indicate lines observed in both directions. A line broken at one end indicates the line is observed only from the end where the line is solid.

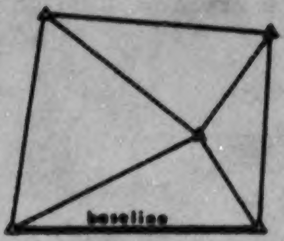


Figure 1

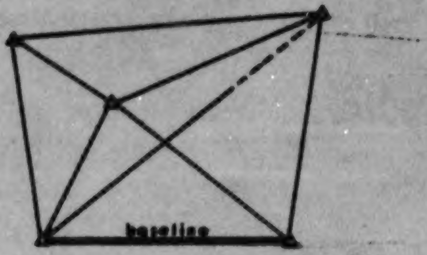


Figure 2

RESPONSE: In Figure 1, D = _____

In Figure 2, D = _____

ANSWER FRAME #36: 1. 9

2. 8

FRAME #37

After you have extracted the four values, you should have a small table that is similiar to the one at the right. You are now ready to begin the actual interpolation.

	30°	32°	35°
95°	13		9
98°			
100°	12		8

To interpolate down, we have to determine three things. The DIFFERENCE between the two values for 30°; the DIFFERENCE between the two values for 35°; and the RATIO or PROPORTION that 98° is between 95° and 100°.

RESPONSE: (1) The difference between the two values for 30° is ________.

(2) The difference between the two values for 35° is ________.

(3) The ratio that 98° is between 95° and 100° is __________.

ANSWER FRAME #9: 14, 15

FRAME #10

DETERMINATION OF "C"

For each triangulation figure, there are certain geometric conditions (C) that exist and must be satisfied. These are: ANGLE CONDITIONS (Ca), the sum of the interior angles of each triangle must equal 180°; and SIDE CONDITIONS (Cs), any side common to two triangles has a common length in each triangle.

RESPONSE: There are certain geometric conditions that must be satisfied in each triangulation figure. These are the __________ CONDITIONS and the ________________ CONDITIONS.

ANSWER FRAME #37: (1) 1
(2) 1
(3) 3/5 or 0.60

FRAME #38

If you got all the answers correct, go on to Frame #39. If any of your answers were incorrect, read this frame for the solutions.

The difference of the two values for 30° is 13 - 12 = 1.

The difference of the two values for 35° is 9 - 8 = 1.

To determine the ratio that 98° is between 95° and 100°, first determine the difference between 98° and 95° (98 - 95 = 3). Then the difference between 100° and 95° (100 - 95 = 5). The ratio you want is the distance that 98° is from 95° (3) over the distance 100° is from 95° (5). In this case the ratio is 3 over 5 or 3/5, which is converted into the decimal 0.60.

——GO ON TO FRAME #39

ANSWER FRAME #10: Side, Angle

FRAME #11

There are two methods of determining "C". One is by using the formula C = Ca + Cs. The second method is called the "Point by Point Build-Up" method. Both methods will give the same C value for any given geometric figure.

RESPONSE: Two methods for determining C are the use of the formula C = Ca + Cs and the ________ __ ________ ________ method.

FRAME #39

If 98° is 0.6 of the way from 95° to 100°, then the value for 98° under the 30° column should be 0.6 of the way from the value for 95° under the 30° column toward the value for 100° under the 30° column.

In other words, the ratio (0.6) times the difference of the two values under the 30° column, subtracted from the value of 95° under the 30° column, gives the value for 98° under the 30° column. The value for 98° under the 35° column is figured in the same manner.

	30°	32°	35°
95°	13		9
98°			
100°	12		8

RESPONSE: (1) The value for 98° under the 30° column is ________.

(2) The value for 98° under the 35° column is ________.

960

ANSWER FRAME #11: Point by Point Build-UP **FRAME #12**

In the formula C = Ca + Cs, Ca is the number of ANGLE CONDITIONS and Cs is the number of SIDE CONDITIONS within the geometric figure.

Ca = n' - s' + 1
Cs = n - 2s + 3

n' = number of lines observed in both directions

s' = number of occupied stations

n = total number of lines in the figure

s = total number of stations in the figure

RESPONSE: (1) The number of angle conditions = ________.
(2) The number of side conditions = ________.

ANSWER FRAME #39: (1) 12.4
(2) 8.4

FRAME #40

If your answers were correct go on to Frame #41. If your answers were not correct read this frame for explanation of solution.

To determine the value for 98° under the 30° column, multiply the difference of the value for 95° under the 30° column (13) and the value for 100° under the 30° column (12), by the ratio that 98° is from 95° to 100° (0.6). Then subtract this product from the value of 95° under the 30° column (13).

The balue for 98° under the 35° column is computed in exactly the same way. See solutions below:

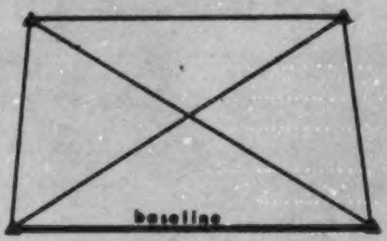
Value for 98° under 30° = 13 - (1 x 0.6) = 13 - 0.6 = 12.4
Value for 98° under 35° = 9 - (1 x 0.6) = 9 - 0.6 = 8.4

GO ON TO FRAME #41

ANSWER FRAME #12: (1) Ca
(2) Cs

FRAME #13

The figure shown below is a quadrilateral, the most common figure used in triangulation. The solid lines indicate that the lines are observed in both directions.



RESPONSE: Using the formula C = Ca + Cs, and the figure shown above, the value for C is _______.

FRAME #41

Your small table should now look similiar to the one shown to the right. You are now ready to interpolate across.

	30°	32°	35°
95°	13		9
98°	12.4		8.4
100°	12		8

To interpolate across is very similiar to interpolating down. First find the difference of the two values for 98°. Then determine the ratio that 32° is from 30° to 35°. Multiply the value of the ratio by the difference in the values for 98°. Subtract the product from the value for 98° under the 30° column. This is your final value and is the value for the polynomial ($\delta A^2 + \delta A \delta B + \delta B^2$) for the triangle ACD in Frame #31.

Determine the final value for the said polynomial in triangle ACD.

RESPONSE: The value for the polynomial for triangle ACD is ______.

962

ANSWER FRAME #13: 4 **FRAME #14**

If you got the correct answer, go on to Frame #15. If you didn't, read the explanation below.

To determine C for the quadrilateral shown in Frame #13, substitute into the formula the numerical values for the letters in the formula.

$C = Ca + Cs$, where $Ca = n' - s' + 1$ and $Cs = n - 2s + 3$

$Ca = 6 - 4 + 1$

$Ca = 2 + 1$

$Ca = 3$

$Cs = 6 - (2 \times 4) + 3$

$Cs = 6 - 8 + 3$

$Cs = 9 - 8$

$Cs = 1$

$C = Ca + Cs$

$C = 3 + 1$

$C = 4$

GO ON TO FRAME #15

ANSWER FRAME #41: 10.8 **FRAME #42**

Your final table should look similiar to the one to the right.

	30°	32°	35°
95°	13		9
98°	12.4	10.8	8.4
100°	12		8

FINAL SOLUTION

Difference of the two values for 98° is $12.4 - 8.4 = 4$

Ratio for 32° is $\frac{32 - 30}{35 - 30} = \frac{2}{5} = 0.4$

Final value is $12.4 - (4 \times 0.4) = 12.4 - 1.6 = 10.8$

GO ON TO FRAME #43

1014

963

FRAME #15

The two figures shown below are other versions of the quadrilateral. Determine the C value for each, using the formula. Solid lines indicate that the line is observed in both directions. A line broken at one end indicates the line is observed only from the end where the line is solid.

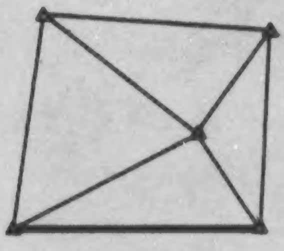


Figure 1

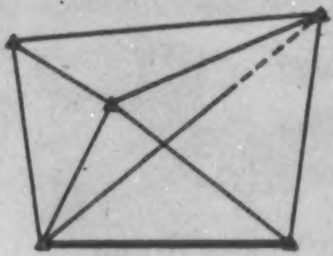


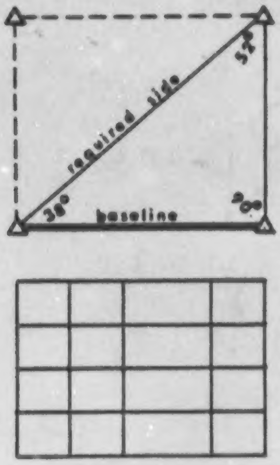
Figure 2

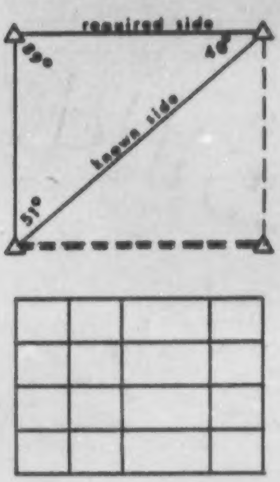
RESPONSE: (1) In figure 1, C = _______.

(2) In figure 2, C = _______.

FRAME #43

Determine the value for the polynomial ($\delta A^2 + \delta A \delta B + \delta B^2$) for the triangles shown in the figures below.


required side
52°
38°
90°
baseline


required side
89°
40°
known side
51°

RESPONSE: (1) Figure 1, ($\delta A^2 + \delta A \delta B + \delta B^2$) = _______.

(2) Figure 2, ($\delta A^2 + \delta A \delta B + \delta B^2$) = _______.

ANSWER FRAME #15: (1) 5
(2) 6

FRAME #16

The Point By Point Build Up Method of determining C is a GRAPHICAL METHOD and no formulas are used. Instead, a set of rules and a sketch are used. THE RULES ARE:

1. Starting with the fixed stations (baseline stations) plot all stations in the figure.
2. The number of angle conditions equals the number of new lines used to control the point, minus one. Only lines observed in both directions are counted.
3. The number of side conditions equals the total number of new lines used to control the station, minus two.
4. Add all conditions found to determine "C".

ANSWER FRAME #43: (1) 2.6
(2) 2.8

FRAME #44

SOLUTIONS TO FRAME #43

In figure 1, the distance angles are 52° and 90°. Enter Table 4-1 with 52° at the top and 90° at the side. Set up table, similiar to the one at the right and interpolate.

	50°	52°	55°
90°	3	2.6	2

In figure 2, the distance angles are 51° and 89°. Enter Table 4-1 with 51° at the top and 89° at the side. Set up table, similiar to the one at the right, and interpolate.

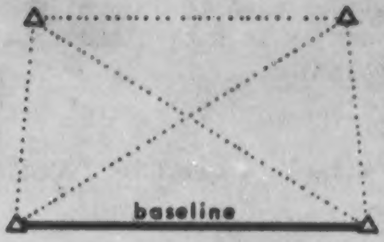
	50°	51°	55°
85°	3		2
89°	3	2.8	2
90°	3		2

GO ON TO FRAME #45

FRAME #17

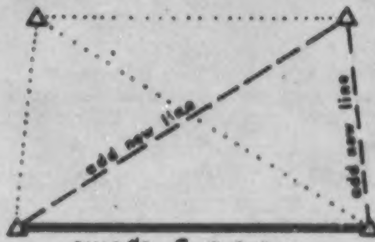
SHOWN BELOW IS AN EXAMPLE OF THE POINT BY POINT BUILD UP METHOD OF DETERMINING C FOR THE QUADRILATERAL SHOWN IN FRAME #13.

RULE 1: Starting with the fixed stations, plot all stations in the figure.

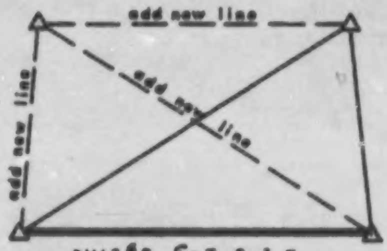


RULE 2: The number of angle conditions (Ca) equals the number of new lines used to control the point, minus one. Only lines observed in both directions are counted.

RULE 3: The number of side conditions (Cs) equals the total number of new lines used to control the station, minus two.



RULE 4: Add all conditions found to determine "C".



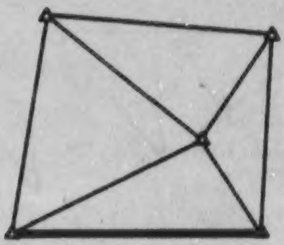
	CONDITIONS	
	ANGLE	SIDE
RULE #2 $C_a = 2-1 =$	1	
RULE #3 $C_s = 2-2 =$		0
RULE #3 $C_a = 3-1 =$	2	
RULE #3 $C_s = 3-2 =$		1
TOTAL GEOMETRIC CONDITIONS "C" =	3 +	1 = 4

NOTICE that the value for "C" is the same as that determined by using the formula C = Ca + Cs.

966

FRAME #18

Determine the value for "C", in the figure shown below, using the Point By Point Build Up Method.



RESPONSE: In the figure above, C = _______.

FRAME #45

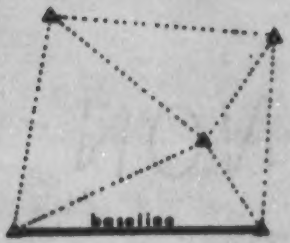
A strength of figure (R) must be computed for EACH ROUTE of COMPUTATION through the figure, no matter what the shape of the figure.

RESPONSE: A "R" value must be determined for __________ __________ of computation through the figure.

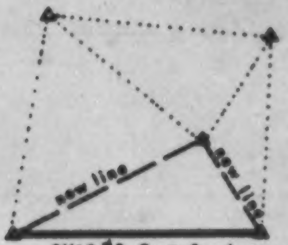
ANSWER FRAME #18: 5

FRAME #19

Use Rule 1 and plot all stations and draw in the base line.



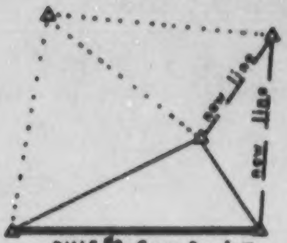
Add new lines used to control first new station. Then use Rules 2 and 3


new line
new line

CONDITIONS

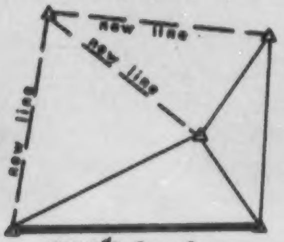
	ANGLE	SIDE
RULE #2, $C_a = 2 - 1 =$	1	
RULE #3, $C_s = 2 - 2 =$		0

Add new lines used to control second new station. Then use Rules 2 and 3 again.


new line
new line

	ANGLE	SIDE
RULE #2, $C_a = 2 - 1 =$	1	
RULE #3, $C_s = 2 - 2 =$		0

Add new lines used to control last new station. Then use Rules 2 and 3 again.


new line
new line
new line

	ANGLE	SIDE
RULE #2, $C_a = 3 - 1 =$	2	
RULE #3, $C_s = 3 - 2 =$		1

RULE #4 TOTAL GEOMETRIC CONDITIONS, "C" = 4 + 1 = 5

FRAME #20

Up to this point you have determined "D", the number of new directions and "C", the number of geometric conditions to be satisfied. You can now determine the first term, $\frac{D-C}{D}$, in the formula $R = \frac{D-C}{D} \sum(\delta A^2 + \delta A\delta B + \delta B^2)$.

For a quadrilateral, having all stations occupied and all directions observed, Frame #8, you have determined that D = 10 and that C = 4 in Frame #13. You can now determine the value for $\frac{D-C}{D}$ by substituting the numbers for letters and solving the problem.

$$\frac{D - C}{D} = \frac{10 - 4}{10} = \frac{6}{10} = 0.6$$

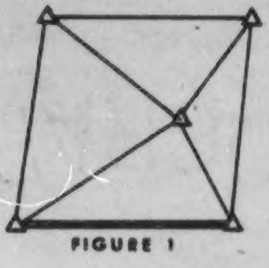


FIGURE 1

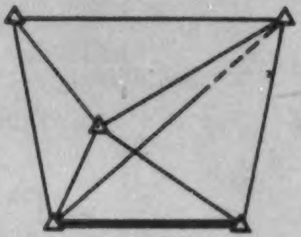


FIGURE 2

RESPONSE: (1) In Figure 1, $\frac{D - C}{D}$ = _______. (See Frames 9 and 15)

(2) In Figure 2, $\frac{D - C}{D}$ = _______. (See Frames 9 and 15)

ANSWER FRAME #45: Each Route

FRAME #46

The smallest computed R value is the R_1 value, which is the STRONGEST route through the figure. The next smallest value is the R_2 value. The next larger values would be the R_3, R_4, R_5, etc.

RESPONSE: The strongest route of computation through the figure is the S__________ computed R value and is designated the _____ value.

ANSWER FRAME #20: (1) 0.64
(2) 0.60

FRAME #21

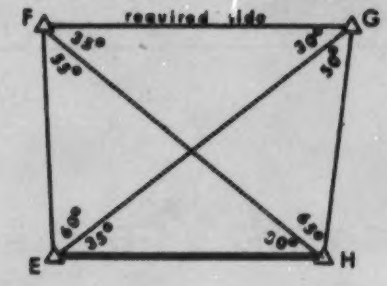
The value for $\frac{D-C}{D}$ is a CONSTANT for a given figure. That is, the value for $\frac{D-C}{D}$ for any quadrilateral having all stations occupied and all directions observed will always be 0.60. The size of the angles of the triangles making up the figure do not affect the quantity $\frac{D-C}{D}$.

RESPONSE: For a given figure, the value for $\frac{D - C}{D}$ is a ____________.

ANSWER FRAME #46: Smallest, R:

FRAME #47

The standard and most common figure used in triangulation is the QUADRILATERAL, with all stations occupied and all directions observed. The figure shown below is a typical QUADRILATERAL.



RESPONSE: The ________________ is the standard figure used in triangulation.

970

ANSWER FRAME #21: Constant **FRAME #22**

ROUTES OF COMPUTATION

Before you begin to determine the value for the polynomial ($\delta A^2+\delta A\delta B+\delta B^2$), you must first determine all possible ROUTES of COMPUTATION through the figure. That is, what are all the possible combinations of triangles that can be used to compute the length of the required line.

RESPONSE: All possible Routes of ______________ through a figure must be determined before you determine the values for the polynomials.

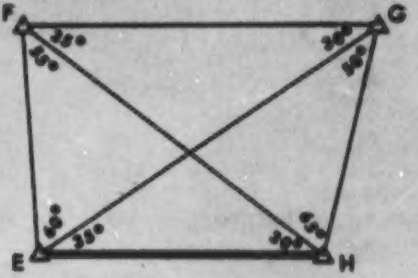
ANSWER FRAME #47: Quadrilateral **FRAME #48**

As noted in Frame #24, there are FOUR routes of computation through a quadrilateral. Shown below is the determination of the FOUR "R" values for the figure shown in Frame #47.

Route	$\frac{D-C}{D}$	Dist ∡'s A and B	($\delta A^2+\delta A\delta B+\delta B^2$) Polynomial	$\sum$($\delta A^2+\delta A\delta B+\delta B^2$) Sum of Polynomials	R
1	0.6	EFH-55° FEH-95° FGH-80° GHF-65°	2 1	3	1.8 = R_1
2	0.6	EGH-50° EHG-95° EFG-98° FEG-60°	3 1	4	2.4 = R_2
3	0.6	EFH-55° FHE-30° EGF-30° FEG-60°	21 19	40	24.0 = R_4
4	0.6	EGH-50° GEH-35° GFH-35° FHG-65°	18 13	31	18.6 = R_3

ANSWER FRAME #22: Computation **FRAME #23**

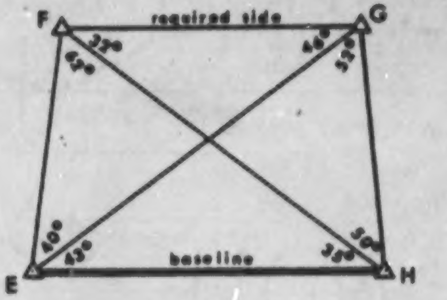
In the figure below, one way to compute the length of line FG would be to first compute the length of the diagonal FH, using the baseline EH as the known side. Then using the computed length of the diagonal FH as the known side, compute the length of the required line FG. This is one route of computation through the quadrilateral.



GO ON TO FRAME #24

ANSWER FRAME #48: Four **FRAME #49**

The figure shown below is another typical quadrilateral, with all stations occupied and all directions observed.



RESPONSE: In the figure above (1) R_1 = ________

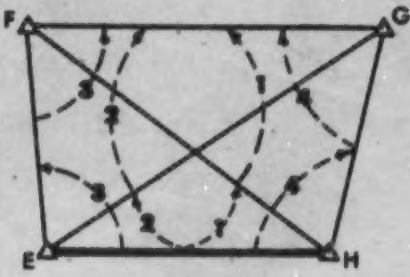
(2) R_2 = ________

(3) R_3 = ________

(4) R_4 = ________

FRAME #24

The quadrilateral, shown below, is considered the standard figure for triangulation nets. In the quadrilateral, there are FOUR possible routes of computation, through the figure, to determine the length of the required line FG, using the baseline EH as the known side.



RESPONSE: In the standard quadrilateral, there are ______ possible routes of computation through the figure.

ANSWER FRAME #49: See solution below

FRAME #50

Route	$\frac{D-C}{D}$	Dist $\measuredangle$. A and B	$(\delta A^2+\delta A\delta B+\delta B^2)$ polynomial	$\sum(\delta A^2+\delta A\delta B+\delta B^2)$ sum of polynomials	R
1	0.6	EGH=52° GHE=85° GFE=94° FEG=40°	2.6 6.0	8.6	5.2 = R_2
2	0.6	HFE=62° FEH=83° HGF=98° GHF=50°	1.6 3.0	4.6	2.8 = R_1
3	0.6	HFE=62° FHE=35° EGF=46° FEG=40°	13.6 15.6	29.2	17.5 = R_3
4	0.6	EGH=52° GEH=43° GFH=32° FHG=50°	11.6 21.0	32.6	19.6 = R_4

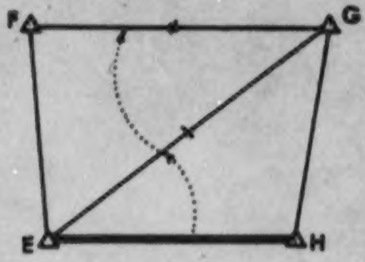
GO ON TO FRAME #51

973

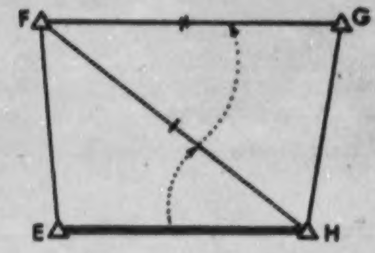
ANSWER FRAME #24: Four

FRAME #25

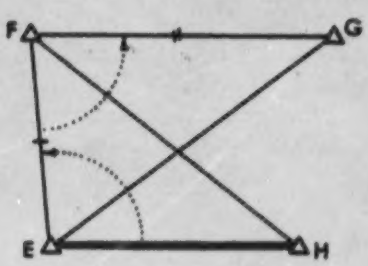
A lot of individuals find it difficult to pick out all the routes by just looking at a single sketch of the figure used. One way to make it a bit easier to determine all the routes of computation is to draw a separate sketch for each possible route. The figures shown below depict the four separate routes for a quadrilateral. Each route is made up of a combination of triangles, going from the known side to the required side.



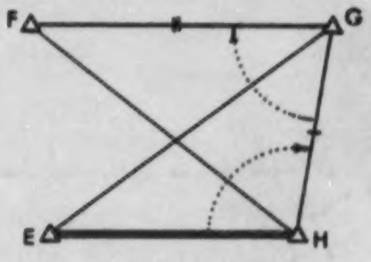
In the triangle EGH, the baseline EH is the known side and the diagonal EG is the required side. In triangle EFG, the diagonal EG becomes the known side and the line FG the required side. The side common to the two triangles used is always first the required side and then the known side.



In the triangle EFH, the baseline EH is the known side and the diagonal FH is the required side. In triangle FGH, the diagonal FH becomes the known side and the line FG the required side.



In the triangle EFH, the baseline EH is the known side and the line EF the required side. In triangle EFG, the line EF becomes the known side and the line FG the required side.



In the triangle EGH, the baseline EH is the known side and the line GH the required side. In the triangle FGH, the line GH becomes the known side and the line FG the required side.

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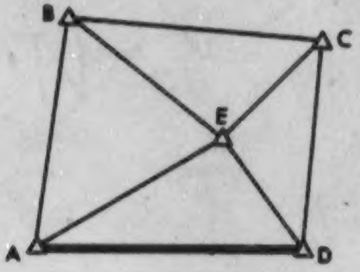
FRAME #26

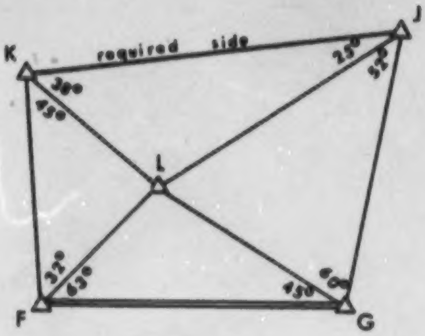
Determine all possible routes of computation through the figure shown below. The final required side is BC.



RESPONSE: There are _____ routes.

FRAME #51

The figure shown below is a quadrilateral with a central point. All stations occupied and all directions observed. Determine all the R values for the figure. REMEMBER that the sum of the interior angles of a triangle must equal 180°.



RESPONSE: (1) R_1 = _____

(2) R_2 = _____

(3) R_3 = _____

(4) R_4 = _____

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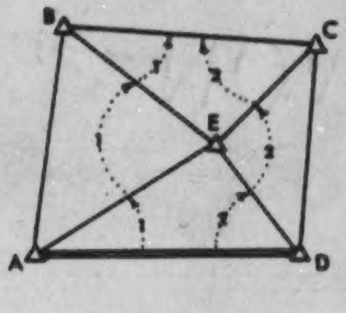
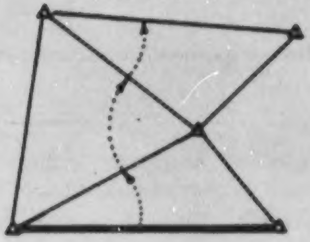
ANSWER FRAME #26: 2

FRAME #27

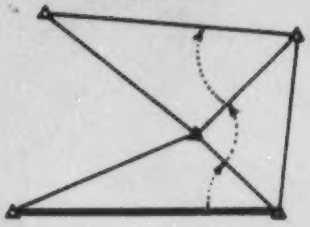
THE SOLUTION TO FRAME #26 IS SHOWN BELOW.



ROUTE 1



ROUTE 2



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FRAME #28

DETERMINATION OF THE POLYNOMIAL ($\delta A^2 + \delta A\delta B + \delta B^2$)

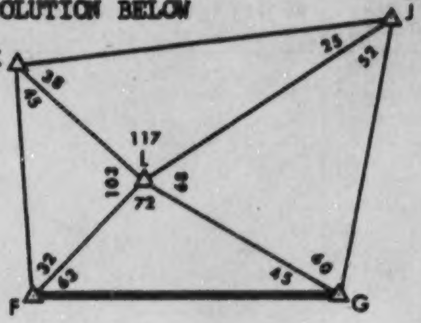
The term ($\delta A^2 + \delta A\delta B + \delta B^2$) is a function of each triangle, varying with the shape of each triangle and the size of the distance angles in the triangle. Therefore, the value of the summation of the polynomials depends upon the value of the polynomial for each triangle.

RESPONSE: The value for the summation of the polynomials depends upon the value for the polynomial in each ________________ used.

Proceed to lower half of page 1.

ANSWER FRAME #51: SEE SOLUTION BELOW

FRAME #52



Route	$\frac{D-C}{D}$	Dist ∡: A and B	($\delta A^2+\delta A\delta B+\delta B^2$)	$\sum(\delta A^2+\delta A\delta B+\delta B^2)$	R
1	0.64	FLG=72° LGF=45°	6.6	46.4	29.7 = R_2
		FKL=45° KFL=32°	23.0		
		KJL=25° KLJ=117°	16.8		
2	0.64	FLG=72° LFG=63°	2.2	14.2	9.1 = R_1
		GJL=52° LGJ=60°	6.2		
		JKL=38° KLJ=117°	5.8		

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STRENGTH OF FIGURE FACTOR

DEGREES	10	12	14	16	18	20	22	24	26	28	30	35	40	45	50	55	60	65	70	75	80	85	90
10	428	359																					
12	359	295	253																				
14	315	253	214	187																			
16	284	225	187	162	143																		
18	262	204	168	143	126	113																	
20	245	189	153	130	113	100	91																
22	232	177	142	119	103	91	81	74															
24	221	167	134	111	95	83	74	67	61														
26	213	160	126	104	89	77	68	61	56	51													
28	206	153	120	99	83	72	63	57	51	47	43												
30	199	148	115	94	79	68	59	53	48	43	40	33											
35	188	137	106	85	71	60	52	46	41	37	33	27	23										
40	179	129	99	79	65	54	47	41	36	32	29	23	19	16									
45	172	124	93	74	60	50	43	37	32	28	25	20	16	13	11								
50	167	119	89	70	57	47	39	34	29	26	23	18	14	11	9	8							
55	162	115	86	67	54	44	37	32	27	24	21	16	12	10	8	7	5						
60	159	112	83	64	51	42	35	30	25	22	19	14	11	9	7	5	4	4					
65	155	109	80	62	49	40	33	28	24	21	18	13	10	7	6	5	4	3	2				
70	152	106	78	60	48	38	32	27	23	19	17	12	9	7	5	4	3	2	2	1			
75	150	104	76	58	46	37	30	25	21	18	16	11	8	6	4	3	2	2	1	1	1		
80	147	102	74	57	45	36	29	24	20	17	15	10	7	5	4	3	2	1	1	1	0	0	
85	145	100	73	55	43	34	28	23	19	16	14	10	7	5	3	2	2	1	1	0	0	0	0
90	143	98	71	54	42	33	27	22	19	16	13	9	6	4	3	2	1	1	1	0	0	0	0
95	140	96	70	53	41	32	26	22	18	15	13	9	6	4	3	2	1	1	0	0	0	0	
100	138	95	68	51	40	31	25	21	17	14	12	8	6	4	3	2	1	1	0	0	0		
105	136	93	67	50	39	30	25	20	17	14	12	8	5	4	2	2	1	1	0	0			
110	134	91	65	49	38	30	24	19	16	13	11	7	5	3	2	2	1	1	1				
115	132	89	64	48	37	29	23	19	15	13	11	7	5	3	2	2	1	1					
120	129	88	62	46	36	28	22	18	15	12	10	7	5	3	2	2	1						
125	127	86	61	45	35	27	22	18	14	12	10	7	5	4	3	2							
130	125	84	59	44	34	26	21	17	14	12	10	7	5	4	3								
135	122	82	58	43	33	26	21	17	14	12	10	7	5	4									
140	119	80	56	42	32	25	20	17	14	12	10	8	6										
145	116	77	55	41	32	25	21	17	15	13	11	9											
150	112	75	54	40	32	26	21	18	16	15	13												
152	111	75	53	40	32	26	22	19	17	16													
154	110	74	53	41	33	27	23	21	19														
156	108	74	54	42	34	28	25	22															
158	107	74	54	43	35	31	27																
160	107	74	56	45	38	33																	
162	107	76	59	48	42																		
164	109	79	63	54																			
166	113	86	71																				
168	122	98																					
170	143																						

TABLE 4-1

411-203-G-010-010

PROGRAMMED LESSON

PHOTOGRAMMETRIC COMPILATION COURSE

RELATIVE ORIENTATION OF IRREGULAR TERRAIN MODELS

JANUARY 1975

DEFENSE MAPPING SCHOOL — FORT BELVOIR, VIRGINIA

TABLE OF CONTENTS

Page

Introductory Summary

[illegible]

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INTRODUCTION

You previously learned the basic methods of Relative Orientation; the single projector methods, (left-to-right and right-to-left) and dual projector method, (swing-swing) and you can see how effective these methods are in removing parallax from regular terrain models. These regular terrain models are oriented by making use of the entire area of overlap, enabling all six positions to be properly located within the model for parallax removal. When a multiplex model contains an irregular area of part land and part water, a change in the basic methods is required. Although only a part of the area of overlap can be utilized in this type of model, it is still possible to remove parallax from those positions that are available.

INSTRUCTIONS

This Programmed Lesson is designed to be a self-paced program and it divides the lesson information into small frames. These frames supply information which you will need to fill in the incomplete "responses" or "action". Study the frame until you can complete the missing portion of the response or action; then check, DO NOT MERELY COPY, your answer with the correct answer, which is printed on the next page. If your answer does not agree, restudy the frame, or if you need assistance, raise your hand and an instructor will help you. This booklet is your property; make notes in it where you think they are needed. Your answers are for your information and are not a test other than proving to yourself whether or not you understand the "response" or "action".

Begin with Frame #1 and continue on to Frame #43. At the end of the text there is a Self-Test where you can check your understanding of the entire lesson.

LESSON OBJECTIVE

Upon completion of this Programmed lesson you will be able to perform Relative Orientation of Irregular Terrain Models using the procedures and specifications as outlined in the TM 5-244 para, 42, 44-47, & 50.

FRAME #1 LEVEL A

Many situations occur in photogrammetric compilation in which the overlapping area of a multiplex model is only partially regular terrain. Such models are known as "irregular" models. The attainment of a parallax-free model is much more difficult when the model itself is irregular. The term "irregular", when used in multiplex, pertains to those spatial models that are part land mass and part water.

FRAME # 22 LEVEL B

1. When clearing parallax from an irregular terrain model the preferable position should be chosen as close as possible to ____________________ ____________________.

1. no response necessary

22. ideal positions

FRAME #2 LEVEL A

1. Irregular Terrain Models are made up of part land mass and part water.

Terrain Models made up of water areas & land areas are called ________________ ________________ Models.

FRAME #23 LEVEL B

a. Preferable positions. Stay as close as possible to the ideal position used for the removal of parallax by a particular adjustment. Choose an appropriate method that will allow the majority of these positions to remain in their proper places.

2. Irregular Terrain.

23. no response necessary.

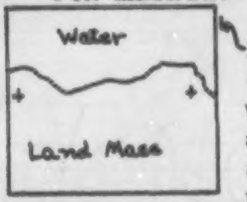
FRAME #3 LEVEL A

2. Irregular terrain models contain part __________ and part __________ __________.

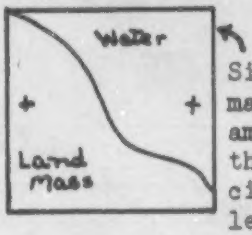
FRAME #24 LEVEL B

The principal points, in some cases, serve as a cue as to which method to use - Right-to-left, Left-to-right (single projection methods, and swing-swing, (dual projection method)

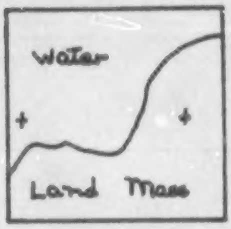
FOR EXAMPLE:



In this example any of the 3 methods would be acceptable since the land mass surrounds the two principal points.



Since the land mass in this example includes the left principal point, the left-to-right method is reccommended.



Since the land mass in this example includes the right principal point, the right-to-left method is recommended.

In some cases, the ________ ________ serve as a cue as to which methods to use.

3. water & land mass

24. principal point

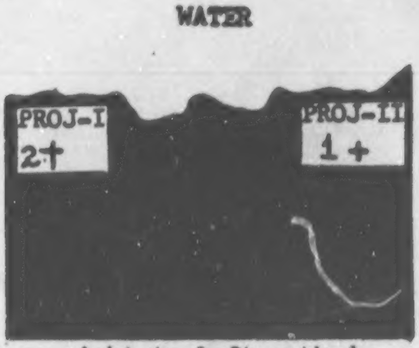
FRAME #4 LEVEL A

By definition then, an Irregular Terrain Model is

____
(your own words)

FRAME #25 LEVEL B

In the situation shown below the water area covers the entire upper portion of the model above the principal points.



Either the left to right or right to left method can be used. Assume we used the right to left method. In orienting the right projector to the left, all the positions & their respective projector movements remain in their normal locations except for positions 3 & 6. Position 3, the "Z" position, is located halfway between positions 1 and 4 along the right edge of the model. Position 6, the check position, is located exactly in the center of the partial land mass. It is advisable to check the entire useable portion of the model, keeping in mind that this is but half of a model and normal parallax perception has been affected accordingly. After each position, check all previous positions for parallax, making sure that all parallax is cleared before continuing.

4. Any statement meaning a spacial model that is part water and part land mass.

25. No Response Necessary

FRAME #5

LEVEL A

4. An example of an Irregular Terrain Model is a combat beach. These beaches and their surrounding areas, both land and water must be accurately mapped before any amphibious operation can take place.

FRAME #26

LEVEL B

In orienting the right projector to the left, (in the last frame) all the positions and their respective projector movements remain in their normal locations except for positions 3&6.

Positions 3 & 6 would normally be found in the upper part of the model. From what you have learned from the last frame, why must points 3 & 6 be moved from their normal positions?

____

____

5. No response necessary.

26. Because one cannot see stereo over water.

992

FRAME # 6 **LEVEL A**

By definition, an irregular terrain model contains water areas. It is, therefore, important that the multiplex operator knows how to utilize the available portions of these water areas correctly, since it is impossible to see Y-parallax over water.

FRAME #27 **LEVEL B**

In using the right to left methods we normally use the Z motion at position No. 3 for clearing parallax. Therefore, wherever position 3 is located, parallax would be cleared using the ____ _________.

6. No response necessary

27. Z Motion

FRAME #7 LEVEL A

There are useable and nonuseable points when clearing parallax on Irregular Terrain Models. When an operator is attempting to set up a model containing water or a coastline, he should not use movable objects such as whitecaps of waves, buoys, or any boats that might appear in the area. The movement of these objects during the interval between the taking of the consecutive photos will give a parallactic angle such that if a moving object is fused it will appear to "float" and have a higher or lower apparent elevation than it actually has, making accurate readings impossible.

We can, therefore, say that a _________ object is a nonuseable point.

FRAME #28 LEVEL B

The movement of Z motion affects the model Radiallyabout the principal point.

When clearing parallax with the Z motion, the model is effected _______________ about the principal point.

7. movable

28. radially

FRAME # 8 LEVEL A

Knowing that movable objects are nonusuable points; name three movable objects found in water.

______ ______ ______

FRAME #29 LEVEL B

Since the effect of the Z motion on the model is radial, we can move position 3 to a point half way between position 1 and position 4 along the right edge of the model.

Why can you move position 3 from its normal position?

______
(In your own words)

______

______

______

8. boats, bouys, whitecaps

29. the Z motion on the model is radial

FRAME #9 LEVEL A

Useable points are stationary objects such as rock structures, jetties, piers and lighthouses. These objects can be used to help the operator set up a model. Since these objects do frequently appear in the water areas it is advisable to always check the water portion of any model.

Objects such as jetties, piers and rock structures are referred to as ____________________ points.

FRAME #30 LEVEL B

From what you have learned in previous classes about the six projector positions for clearing parallax, what is the sixth position used for?

____

In your own words.

____

____

999

9. useable

30. It is a check point.

1051

1000

FRAME #10 **LEVEL A**

1. What type of Object would make a usable point?

2. What type of point would a bouy or a boat make?

FRAME #31 **LEVEL B**

When using the right-to-left method of clearing a normal model, you would normally find check points six located where?

10. 1. rock structure, jetty, pier or lighthouse, any or all would be correct.

    2. nonuseable point

31. upper left hand corner

FRAME #11 LEVEL A

The two types of points located in water areas are useable and non-useable points.

The type of point that would allow you to see stereo would be a ________________ point.

FRAME #32 LEVEL B

Since there is water where position six is normally located you must move position 6 to the center of the land mass.

In this first situation for clearing an Irregular model you would place the check point in the center of the usable ___________ _________.

1003

11. usable

32. land mass

1004

FRAME #12 LEVEL A

The following are objects that move.

White caps of waves, buoys, or any boats that appear in the area.

These objects are nonusable points because they ________, or change location easily.

FRAME #33 LEVEL B

It is advisable that you check the useable portion of the model, keeping in mind that this is but half of a model and normal parallax perception has been affected accordingly.

1056

12. move

33. no response is necessary

1006

FRAME #33 LEVEL A

The basic methods of relative orientation utilize six ideal positions strategically located within the model for the removal of parallax. However, irregular models containing water areas make the utilization of all of these ideal positions impossible in almost every situation since parallax cannot be cleared over water. Therefore, alternate positions must be chosen for each method. These positions are dictated first by the available land area and second, by the effect of each motion on the shape of the model. Parallax can be removed by a particular projector movement only at certain critical positions within the model.

FRAME #34 LEVEL B

You should choose an appropriate method that will allow the majority of these preferred positions to remain as close as possible to their _______________ positions.

13. no response necessary

34. Ideal

FRAME #14 LEVEL A

Since the ideal positions for clearing parallax over water is impossible in almost every situation, alternate positions must be chosen for each method. These positions are determined by the available ______________ area and the effect of each motion on the shape of the model.

FRAME #35 LEVEL B

When picking a preferable position stay as close as possible to the ideal position.

Whatever motion you use for clearing parallax at the ideal position should be used for the corresponding ___________ position.

14. land

35. preferable

1061

FRAME #15 LEVEL A

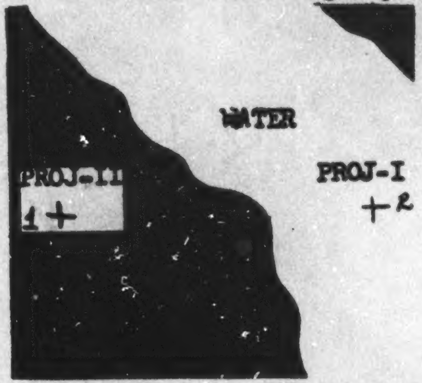
1. What two factors determine where the alternate positions for Y-parallax removal will be located?

a. ____

b. ____

FRAME #36 LEVEL B

In the situation below the water area extends from the upper left portion of the model diagonally across to the lower right portion.



The left to right method is preferred for the relative orientation of this model. In orienting the left projector to the right, all the positions & their respective projector movements remain in their normal locations except for position 2 and 5. Position 2, the "swing" position, is located along the flight line as close as possible to the principal point of the right projector. Position 5, the "Y-tilt" position, is located along the bottom edge at the extreme right of the existing land mass. After each position, check all previous positions for parallax, making sure that all parallax is cleared before continuing.

15. a. Available land area

    b. effect of each motion on the shape of the model

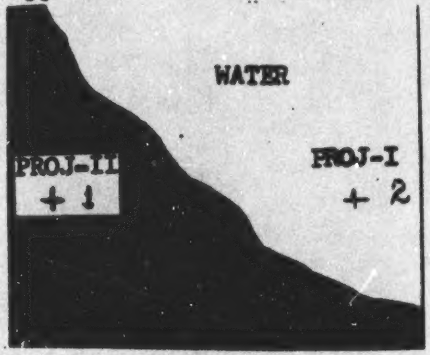
36. No Response Necessary

FRAME #16 **LEVEL A**

1.e. The basic methods of relative orientation utilize six IDEAL Positions located within the stereo model.
In every stereomodel thetn are six _________ position.

FRAME #37 **LEVEL B**

In the situation below the water area covers the entire upper right corner of the model, extending from the upper left corner to below the principal point along the right edge.



The left to right method is used for the relative orientation of this model. In orienting the left projector to the right, all the positions and their respective projector movements remain in their normal locations except for positions 2 and 6. Position 2, the "swing" position, is located as close as possible to the principal point on the right side of the model along the flight line. Special care should be taken when making this adjustment since the parallax is not being observed at the principal point where the rotation will take place. Position 6, the check position, is located in the center of the model halfway between the flight line and bottom edge. Again, do not forget to check the entire usuable portion of the model for parallax.

16. Ideal

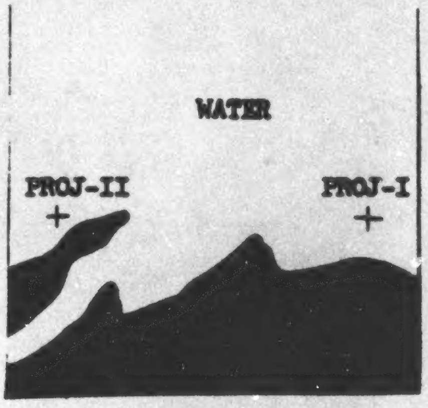
37. No Response Necessary

FRAME #17 LEVEL A

Irregular terrain models make the utilization of all _________ ideal positions impossible.

FRAME #38 LEVEL B

In the situation below the water area covers the entire upper portion of the model including the principal points. An inlet extending from the center of the model to the lower left side divides the remaining area into two partial land masses.



Either the left-to-right or right-to-left method can be used for the relative orientation of this model; however, the left-to-right method is preferred because the land area on the left side of the model is closer to the left principal point than the land area on the right is to the right principal point. In orienting the left projector to the right, the only positions that remain in their normal locations are position 4, the "X-tilt" position, and position 5, the "Y-tilt" position. Position 1, the "Y" position, is located as close to the left principal point as the existing land mass will allow. Position 2, the "swing" position, is located as close as possible to the right principal point. Position 3, the "Z" position, is located along the left edge of the model, approximately halfway between positions 1 and 4. Position 6, the check position, is located in the center of the land area; however, careful checks throughout the entire land area should be made.

17. six

38. No Response Necessary

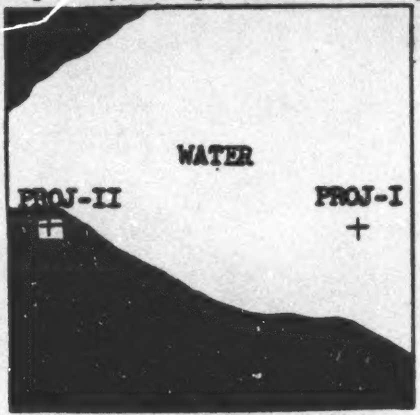
FRAME #18 LEVEL A

Since you will not be able to use all six ideal positions for clearing parallax in an Irregular terrain model, you must choose an alternate position.

In removing parallax in an Irregular Terrain model, ________________ positions must be chosen.

FRAME #39 LEVEL B

In the situation below the water area covers the entire upper portion of the model including the right principal point, except for a small piece of land in the upper left corner.



Which method would you use for the relative orientation of this model?

1. left-to-right
2. right-to-left
3. swing-swing

1017

18. alternate

39. The left-to-right method is the correct method for the relative orientation of the spacial model. The left principal point surrounded by land mass is the cue to which method should be used.

FRAME #19 LEVEL A

These alternate positions are affected by two important factors:

1. the available land area
2. the effect of each motion (x, y or z) on the shape of the model

The available land area will effect the _________ ___________ used in performing Relative Orientation as well as the motions x, y & z.

FRAME #40 LEVEL B

As stated previously, the ________________ ___________, in some cases, serve as a cue as to which method to use: right-to-left, left-to-right or swing-swing.

1019

19. alternate positions

40. Principal Points

1071

FRAME #20 LEVEL A

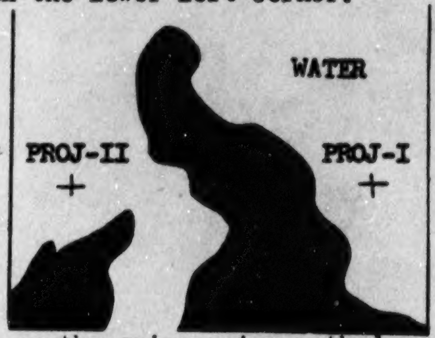
When choosing an alternate position, what two important items must be considered?

1. ____

2. ____

FRAME #41 LEVEL B

In the situation below the water area covers the two principal points and surrounds a peninsula, located in the center of the model, that extends from just below the upper left corner to the lower right corner; also, a small land mass exists in the lower left corner.



Either the left-to-right or the swing-swing method can be used for the relative orientation of this model, but the left-to-right method is preferred since the principal points fall in the water portion of the model , making accurate adjustments with the swing motions very difficult. In orienting the left projector to the right, only two positions remain in their normal locations: position 4, "X-tilt" position, and position 5, "Y-tilt" position. Position 1, the "Y" position, is located as close as possible to the upper left corner. Of course, the check position, position 6, is located in the center of the model halfway between the flight line and the bottom edge; but as before, the search for parallax is not confined to this narrow limit.

1021

1. available land area

2. effect of each motion on the shape of the model

41. No response necessary.
(Turn to page 43)

1073

FRAME #21 LEVEL A

Allowable positions. When the water portion of an irregular model makes an alternate position for parallax resolution necessary, it is important to know where the critical positions are in a model at which parallax can be observed and cleared by the different projector movements. The following allowable positions should be utilized: Parallax can be removed at all six positions by using the "Y" motion, but the two positions located near the principal points are preferred. "Swing" parallax is removed at the principal points or as close as possible to the principal points along the flight line. Parallax can be removed by the "Z" motion in the four corners (preferably at the top) or along the edges of the model. The principal point positions cannot be used since they do not move in the "Y" direction when this "Z" movement is made. "Y-tilt" parallax can be cleared at the top or bottom corner on the left side of the model if the right projector is used, or the top or bottom corner on the right side if the left projector is used. The bottom corners are preferable. "X-tilt" parallax can be removed at all six positions or along the top or bottom edge. The particular procedure used will dictate where this "X-tilt" parallax is to be cleared.

(Return to page 1 for Frame 22)

1023

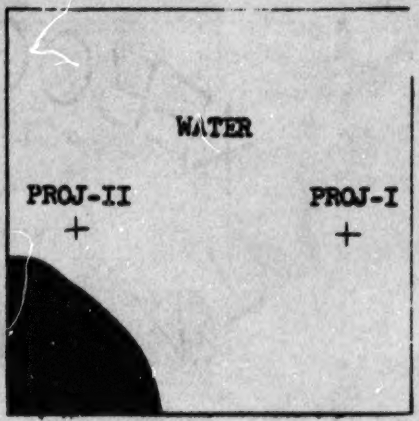
21. No response necessary.

1075

1024

FRAME #42

In the situation below the only land portion of this model is found in the lower left corner.

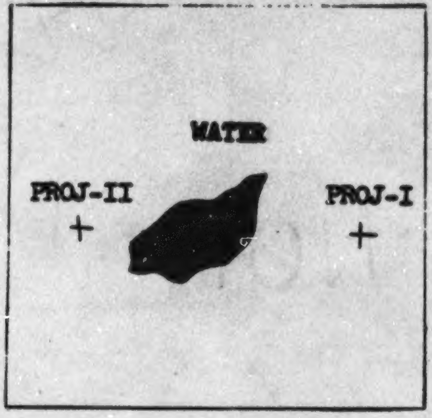


The brevity of the usable land portion of this model makes any method of relative orientation very difficult, but the left-to-right, single projector method is preferred over the other methods. Only position 4, the "X-tilt" position, remains in its proper location. Position 1, the "Y" position, is located in the extreme upper corner of the land area, as close to the left principal point as possible. Position 2, the "swing" position, is located on the shoreline half way between the bottom edge and left side of the model. Position 3, the "Z" position, is located along the left side, half way between positions 1 and 4. Position 5, the "Y-tilt" position, is located in the extreme lower corner of the land area as close as possible to the lower right corner of the model. The remaining land area is checked thoroughly to make sure all parallax has been cleared throughout the model. After each position, check all previous positions for parallax, making sure that all parallax is cleared before continuing.

No response necessary.

FRAME #43

In the situation below a small island is located in the center of this model, completely surrounded by water on all sides.



Any of the standard methods of relative orientation is impossible to use in this situation due to the small area of land present. Therefore, a "modified" dual-projector or swing-swing method is used with extreme care. Because of the limited land area, only three positions are utilized for the removal of parallax. Position 1 is located near the principal point of the left projector along the flight line. Parallax existing here is removed by the motion of the left projector. Position 3 is located either in the bottom left corner or upper right corner of the model. The "Z" motion is used for parallax resolution at this position. Checks are made over the remaining land area to ensure a parallax-free model.

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44. SELF TEST

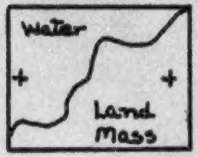
1. In your own words, define the term Irregular Terrain Model. (Frame #1)

2. Name two non-usuable points. (Frame #7)

3. Name two usuable points. (Frame #9)

4. Name one factor which will determine where the alternate positions for Y-parallax removal will be located. (Frame #15)

5. In the situation below, which method would you use in removing parallax from this stereo model?



6. True or False - When picking a preferable position it is advisable to stay as close as possible to the ideal position (Frame #35)